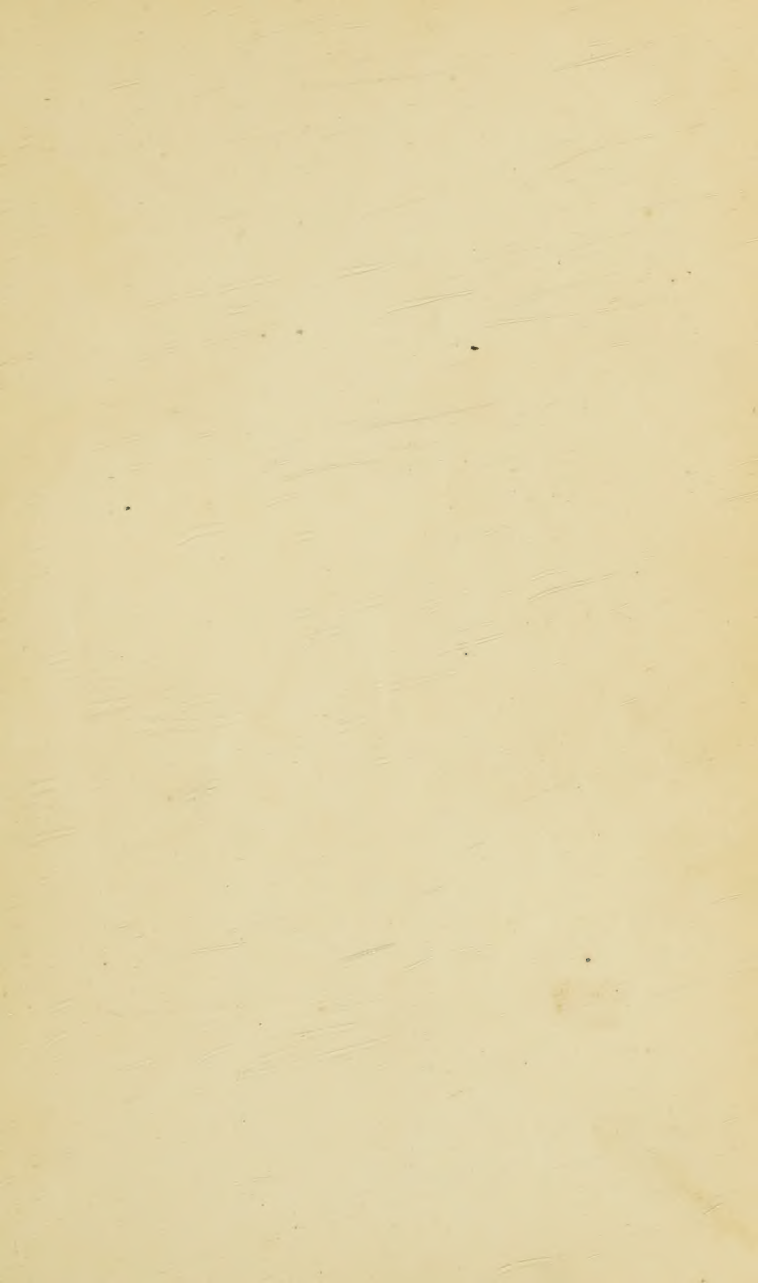








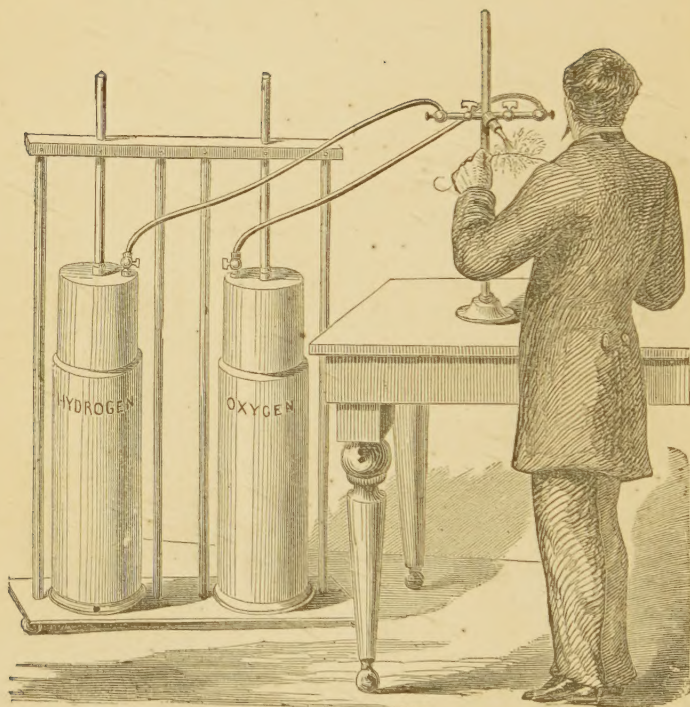
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OXYHYDROGEN BLOW-PIPE.

A

FOURTEEN WEEKS

COURSE IN CHEMISTRY.

BY

J. DORMAN STEELE, A.M.,
PRINCIPAL OF ELMIRA FREE ACADEMY.

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PREFACE.

IN the preparation of this little volume the author lays no claim to originality: his has been the far humbler task of endeavoring to express, in simple, interesting language, a few of the principles and practical applications of Chemistry. There is a large class of pupils in our schools who can pursue this branch only a single term, the time assigned to it in most institutions. They do not intend to become chemists, nor even professional students. If they wander through a large text-book, they become confused by the multiplicity of strange terms, which they cannot tarry to master, and, as the result, too often only "see men as trees walking." Attempts have been made to reach this class by omitting or disguising the nomenclature; but this robs the science of its mathematical beauty and discipline, while it does not fit the student to read other chemical works or to understand their formulæ. The author has tried to meet this want by omitting that which is perfectly obvious to the eye—that which everybody already knows—that which could not be long retained in the memory—and that which is essential

only to the chemist. He has not attempted to make a reference-book, lest the untrained mind of the learner should become clogged and wearied with a multitude of detail. He has sought to make a pleasant study which the pupil can master in a single term, so that all its truths may become to him "household words." Botany, Natural Philosophy, and Physiology are omitted, since they are now pursued as separate branches. Unusual importance is given to that practical part of chemical knowledge which concerns our every-day life, in the hope of bringing the school-room, the kitchen, the farm, and the shop in closer relationship. This work is designed for the instruction of youth, and for their sake clearness and simplicity have been preferred to recondite accuracy. If to some young man or woman this becomes the opening door to the grander temple of Nature beyond, the author will be abundantly repaid for all his toil.

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ELEMENTARY CHEMISTRY.

INTRODUCTION.

CHEMISTRY treats of the *specific* properties of matter and the composition of bodies. Examples: gold is yellow; water is composed of two gases, hydrogen and oxygen.

ORGANIC CHEMISTRY deals with those substances that have been produced by life. Examples: flesh, wood. INORGANIC CHEMISTRY is confined to those bodies that have not been formed by life. Examples: metals, rocks.

An ELEMENT is a kind of matter which has never been separated into anything else. Examples: silver, iron. There are about 65 in all, of which 52 are metals, and 13 metalloids or non-metallic substances.

CHEMICAL AFFINITY is that force that causes the elements of matter to unite and form new compounds. It acts at distances so slight as to be insensible, and upon the most dissimilar substances: the more dissimilar the stronger the union. Example: a little chlorate of potassa and sulphur mixed in a mortar will not combine, but a slight pressure of the pestle will bring them within the range of attraction, and they will burn with a loud explosion.

Nothing in the nature or appearance of any element indicates its chemical affinity. We can only tell by trial with what it will combine. This attraction is not a mere freak of nature, but a law stamped upon matter by God himself for wise and beneficent purposes.

COMPOUNDS are utterly unlike their elements in all their properties. Examples: yellow sulphur and white quicksilver form red vermilion; the inert nitrogen and the oxygen of the air constitute a corrosive acid—aquafortis; charcoal, hydrogen, and nitrogen produce the deadly prussic acid; solid charcoal and sulphur make a colorless liquid; poisonous and offensive chlorine combines with the brilliant metal sodium to form common salt.

HEAT and LIGHT favor chemical action, and frequently develop an affinity where it seemed to be wanting. The former especially, by its expansive force, tends to drive the elements of a compound without the range of old attractions and within that of new ones. Examples: gun-cotton, when lying in the air, is apparently harmless, but a spark of fire will produce a brilliant flash, and it disappears as a gas: nitrate of silver turns black in the sun, by the action of the light.

SOLUTION also aids in chemical change, as it destroys cohesion and leaves the atoms free to unite. Example: carbonate of soda and tartaric acid mixed in a glass will not combine, but a little water added will produce a violent effervescence.

The CHEMICAL EQUIVALENT of an element is the

proportion by weight in which it unites with other elements. There is no chance-work in nature. No matter under what circumstances a compound is formed, the proportion of its elements is the same. Example: the carbonic acid produced amid the roar of a conflagration or the explosion of a volcano is identical with that made in the quiet burning of a match.

The ATOMIC THEORY, which lies at the basis of chemistry, as now understood, supposes—

1st. That bodies are composed of individual and unchangeable atoms.

2d. That the chemical equivalent represents the relative weight of the atoms of different kinds.

3d. That compounds are formed by the union of different kinds of atoms in the proportion of their equivalents, or multiples of their equivalents.

4th. That the chemical equivalent of a compound is equal to the sum of the chemical equivalents of its elements.

NOMENCLATURE.—The elements which were known anciently have retained their names. Those discovered more recently are named from some peculiarity. Examples: chlorine, from its green color; bromine, from its bad odor. Of late the uniform termination *um* has been adopted.

SYMBOLS.—The first letter of the English name has been taken as the symbol. When that would produce confusion, the Latin name has been substituted, and in some cases the second letter added. Examples: carbon and chlorine both commence with

C; so the latter takes Cl for its symbol. Silver and silicon both begin with Si, hence the former assumes Ag, from its Latin name, *Argentum*. If more than one equivalent of an element is used in forming a compound, this is shown by writing the number below the symbol. Example: O_2 indicates two equivalents of O. In the use of the following table, the symbol should recall, not the name of the element alone, but the relative weight of its atoms. Example: O means 8 parts of oxygen by weight.

TABLE OF ELEMENTS AND EQUIVALENTS.

ELEMENTS.	Symbol.	Equivalent.	ELEMENTS.	Symbol.	Equivalent.
Aluminum.	Al.	13.70	<i>Niobium</i> (Columbi-		
Antimony (Stibium),	Sb.	129.00	um),	Nb.	48.80
Arsenicum,	As.	75.00	Nitrogen,	N.	14.00
Barium,	Ba.	68.50	<i>Norium</i> ,	No.	
<i>Bismuth</i> ,	Bi.	210.30	<i>Osmium</i> ,	Os.	99.40
Boron,	Bo.	10.90	Oxygen,	O.	8.00
Bromine,	Br.	80.00	<i>Palladium</i> ,	Pd.	53.20
<i>Cadmium</i> ,	Cd.	56.00	Phosphorus,	P.	31.00
<i>Cesium</i> ,	Cs.	132.40	Platinum,	Pt.	98.60
Calcium,	Ca.	20.00	Potassium (Kalium),	K.	39.00
Carbon,	C.	6.00	<i>Rhodium</i> ,	Ro.	53.20
<i>Cerium</i> ,	Ce.	46.00	<i>Rubidium</i> ,	Rb.	85.36
Chlorine,	Cl.	35.50	<i>Ruthenium</i> ,	Ru.	52.11
<i>Chromium</i> ,	Cr.	26.30	<i>Selenium</i> ,	Se.	39.70
<i>Cobalt</i> ,	Co.	29.50	Silicon,	Si.	14.00
Copper (Cuprum)	Cu.	31.70	Silver (Argentum),	Ag.	108.00
<i>Didymium</i> ,	D.	48.00	Sodium (Natrium),	Na.	23.00
<i>Erbium</i> ,	E.		<i>Strontium</i> ,	Sr.	43.80
Fluorine,	F.	19.00	Sulphur,	S.	16.00
<i>Glucinum</i> ,	Gl.	4.70	<i>Tantalum</i> ,	Ta.	68.81
Gold (Aurum),	Au.	196.44	<i>Tellurium</i> ,	Te.	64.50
Hydrogen,	H.	1.00	<i>Terbium</i> ,	Tb.	
Iodine,	I.	126.80	<i>Thallium</i> ,	Tl.	
<i>Iridium</i> ,	Ir.	98.60	<i>Thorium</i> ,	Th.	59.50
Iron (Ferrum),	Fe.	28.00	Tin (Stannum),	Sn.	56.00
<i>Lanthanum</i> ,	La.	46.00	<i>Titanium</i> ,	Ti.	25.00
Lead (Plumbum),	Pb.	103.60	<i>Tungsten</i> (Wol-		
<i>Lithium</i> ,	L.	7.00	fram),	W.	92.00
Magnesium,	Mg.	12.00	<i>Uranium</i> ,	U.	60.00
Manganese,	Mn.	27.48	<i>Vanadium</i> ,	V.	68.50
Mercury (Hydrargy-			<i>Yttrium</i> ,	Y.	
rum),	Hg.	100.00	Zinc,	Zn.	32.50
<i>Molybdenum</i> ,	M.	48.00	<i>Zirconium</i> ,	Zr.	22.40
<i>Nickel</i> ,	Ni.	29.50			

A BINARY COMPOUND is a union of two elements, and in reading it the electro-negative is placed first and distinguished by the termination *ide*. Examples: chlorine and sodium form chloride of sodium; iodine forms iodides. In the case, however, of phosphorus, carbon, and sulphur, the termination *uret* is generally used. Example: iron and sulphur form sulphuret of iron. In writing the symbols the electro-positive element is placed first. An OXYD is a compound of O with an element. One equivalent of O is called the protoxyd; two, the deutoxyd or binoxyd; three of O to two of the other element, the sesquioxyd. Oxygen being negative to iron, when united they form an oxyd of iron, which is, therefore, written FeO ; the deutoxyd of iron is FeO_2 ; the tritoxyl of iron is FeO_3 ; the sesquioxyd, Fe_2O_3 .

Binary compounds are divided into three classes—ACIDS, BASES, and NEUTRALS.

An ACID is generally sour, and reddens blue litmus and green cabbage solution. It unites with bases to form salts, which is the real test of an acid. Acids are of two kinds—Oxacids and Hydracids; the former contain O, the latter, H. The oxacids are named from the element with which the O unites, the termination indicating their strength—*ic* the stronger and *ous* the weaker. Example: sulphur forms two acids of different strength—sulphuric and sulphurous. If an acid has been found containing more O than the stronger, it takes the

prefix *per*; if one having less O, the prefix *hypo*.
Examples.

Chloric acid.....	ClO_5 .
Chlorous acid.....	ClO_3 .
Perchloric acid.....	ClO_7 .
Hypochlorous acid.....	ClO .

The hydracids combine the names of both elements. Examples: hydrogen and chlorine form hydrochloric acid; hydrogen and sulphur make hydrosulphuric acid.

A BASE is a substance that unites with an acid to form a salt. An alkali is a base that, in addition, has a soapy taste and feel, and changes red litmus to blue, and red cabbage to green. It turns the *ium* of its termination to *a*. Example: NaO is called the oxyd of sodium, and also soda. The alkalies neutralize the acids, and each restores the color removed by the other.

SALTS are ternary compounds, being composed of three elements. They are formed by the union of an acid and a base. In naming a salt the termination of the acid is changed—an *ic* acid forming an *ate* compound, and an *ous* acid an *ite* compound. The O combined in the base is sometimes omitted. Ex.: FeO.SO_3 is read sulphate of iron, and not sulphate of the protoxyd of iron; CuO.SO_3 , sulphate of copper; but CaO.SO_2 , sulphite of lime.

NEUTRALS have neither the properties of an acid

nor a base. Examples: NaCl , chloride of sodium; KI , iodide of potassium.

A FORMULA is an algebraic statement of the symbols and relations of several compounds. The $+$ sign indicates a feeble attraction or a mere mixture. The $=$ sign indicates conversion into. The period denotes a combination. The brackets and coefficients are used as in algebra.

The following list of symbols is given for practice and a *thorough drill*.

PRINCIPAL ACIDS.

Sulphuric Acid (Oil of Vitriol).....	SO_3
Nitric Acid (Aquafortis).....	NO_5
Chloric Acid.....	ClO_5
Phosphoric Acid.....	PO_5
Carbonic Acid.....	CO_2
Sulphurous Acid.....	SO_2
Nitrous Acid.....	NO_4
Hydrochloric Acid.....	HCl

THE ALKALIES.

P—otassa (Potash).....	KO
S—oda.....	NaO
A—mmonia,.....	NH_3
L—ime.....	CaO
M—agnesia.....	MgO

SALTS.

Sulphate of Iron (Green Vitriol).....	$\text{FeO}.\text{SO}_3$
Sulphate of Copper (Blue Vitriol).....	$\text{CuO}.\text{SO}_3$
Sulphate of Zinc (White Vitriol).....	$\text{ZnO}.\text{SO}_3$

Sulphate of Potash.....	KO.SO ₃
Chlorate of Potash.....	KO.ClO ₅
Nitrate of Soda.....	NaO.NO ₅
Nitrate of Potash (Saltpetre).....	KO.NO ₅
Carbonate of Lime (Limestone, Chalk).....	CaO.CO ₂
Carbonate of Soda (Soda).....	NaO.CO ₂
Bicarbonate of Potash (Saleratus).....	KO.2CO ₂

Sulphite of Soda.....	NaO.SO ₂
Sulphide of Iron.....	FeS
Sulphuret of Iron.....	FeS
Chloride of Sodium (common salt).....	NaCl
Binoxyd of Manganese.....	MnO ₂
Protoxyd of Hydrogen (water).....	HO
Sesquioxyd of Iron (iron-rust).....	Fe ₂ O ₃

MATHEMATICS OF THE LAW OF EQUIVALENTS.—The beauty and simplicity of the Divine law of harmony that runs like a silken thread through all nature, giving unity and completeness everywhere, are best seen by some practical applications. It is evident, from the fourth principle of the atomic theory, that the proportion of any element in a compound is equal to its equivalent divided by the equivalent of the compound. Example: $HO = 1 + 8 = 9$; hence the proportion of H in any quantity of water is $\frac{1}{9}$, and the proportion of O is $\frac{8}{9}$. Again: the proportion of that element or constituent in a given weight of the compound must be equal to the weight multiplied by this fraction we have just named. Example: In 4 lbs. of HO there are $4 \times \frac{1}{9}$ lb. of H = $\frac{4}{9}$ lb., and $4 \times \frac{8}{9}$ lb. of O = $\frac{32}{9} = 3\frac{5}{9}$ lbs. For conveni-

ence we can put this thought into the following algebraic form, under which should be solved the examples which follow, and many other similar ones, which the ingenuity of teacher and scholar will suggest. The book should be searched for symbols of compounds, and this part referred to throughout the study.

Weight of one constituent = weight of given quantity $\left\{ \begin{array}{l} \text{Equivalent of the constituent} \\ \text{Equivalent of the compound} \end{array} \right.$

1. In making O from chlorate of potash ($\text{KO} \cdot \text{ClO}_3$), how much can be obtained from two pounds of the salt? [See page 227, Problems.]

2. In making H zinc is used. How much sulphate of zinc ($\text{ZnO} \cdot \text{SO}_3 + 7\text{HO}$) will be formed from 2 lbs. of the metal?

3. How much SO_3 will be required to make 50 lbs. sulphate of iron ($\text{FeO} \cdot \text{SO}_3 + 7\text{HO}$)?

4. The equivalent of the chloride of sodium (salt) is 58.5. In 10 lbs. there are $6\frac{8}{117}$ lbs. of chlorine; what is the equivalent of Cl?

5. In 20 grains of bromide of potassium there are $6\frac{6}{115}$ grains of potassium; the equivalent of potassium being 39, what is the equivalent of the bromide of potassium?

6. In 14 lbs. of iron-rust (Fe_2O_3) how much O?

7. In 20 lbs. of glass ($\text{NaO} \cdot \text{SiO}_2 + \text{CaO} \cdot \text{SiO}_2$) how many lbs. of sand (SiO_2)?

8. In a 25 lb. sack of salt (NaCl) how many lbs. of the metal sodium?

INORGANIC CHEMISTRY.

THE METALLOIDS.

OXYGEN.

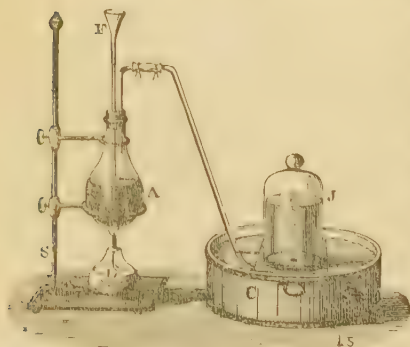
Symbol, O Equivalent, 8 Specific Gravity, 1.1.

THE name O means acid-former, and was given because it was supposed to be the essential principle of all acids; but hydrogen has since been found to possess the same property.

Source.—O is the most abundant of all the elements—comprising $\frac{1}{5}$ of the air, $\frac{8}{9}$ of the water, $\frac{3}{4}$ of all animal bodies, and $\frac{1}{2}$ of the crust of the earth.

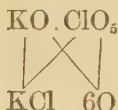
Preparation.—The simplest method of making O

for experimental purposes is to heat a mixture of chlorate of potash and black oxyd of manganese in a retort, and collect the gas over a pneumatic cistern, as in the accompanying illustration.



Preparing O.

The reaction --the chemical change--is as follows :

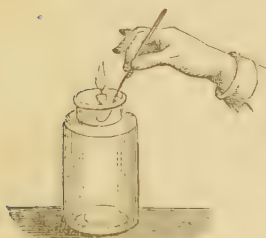


The Cl of the chloric acid unites with the K of the potash, forming KCl, chloride of potassium ; and the 5 atoms of O in the chloric acid and the atom of O in the potash, making 6 atoms of O, pass off as a gas.

A Curious Fact.—If the chlorate of potash were heated alone, when the requisite temperature was reached the gas would be liberated with very great rapidity. Sometimes, indeed, the change would be instantaneous—the solid of scarcely a cubic inch becoming in the twinkling of an eye a gas of 300 cubic inches, and, with an explosion like gunpowder, rending the retort into a thousand fragments. If, however, we mix with the chlorate of potash a little black oxyd of manganese, the gas will come off quietly and safely, a bubble at a time. At the conclusion of the process, the MnO_2 (the binoxyd, or black oxyd of manganese) will be found unchanged. The reason of this wonderful action is beyond our comprehension. It would seem that powdered glass or sand should produce the same result ; but, on trial, they fail. This influence of one body over another, by its mere presence, is called *catalysis*.

Properties.—O has no odor, color, or taste. It combines with every element except fluorine. From some of its compounds it can be set free by the stroke of a hammer, while from others it can be liberated only by the most powerful means. Its union with a substance is called *oxydation*, and the product an *oxyd*. It is a most powerful supporter of combustion.

Example: By blowing quickly upward upon a



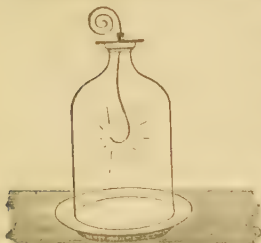
Candle in oxygen.

candle extinguish the flame, and leave a glowing wick.

If this be plunged into a jar of pure O, it will burst into a brilliant blaze. The experiment may be repeated many times before the gas is exhausted. Carbonic acid is

formed by the combustion.

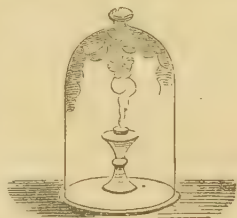
Example: If a watch-spring be straightened in a



Watch-spring in oxygen.

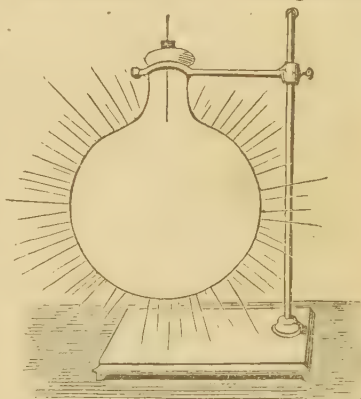
spirit-lamp, and then tipped with melted sulphur, on igniting this and lowering it into a jar of O, the steel will crackle into a shower of fiery stars, and melted globules of oxyd of iron will fly in every direction.

Example: Ignite a bit of sulphur placed on a stand, and invert over it a jar of O: it will burn with a beautiful blue light, and the fumes of sulphurous acid (SO_2) will circle about the receiver in curious concentric rings.



Sulphur in oxygen.

Example: Place in the bottom of a “deflagrating spoon” a little fine, dry chalk; then wipe a bit of phosphorus very carefully and quickly between pieces of blotting-paper; lay this upon the chalk, and, holding the spoon over a large jar of O, ignite the phosphorus with a heated wire, and lower it steadily into the gas. The phosphorus will burst into a blinding flood of light, while dense fumes of phosphoric acid (PO_5) will roll down the sides of the jar.



Phosphorus in oxygen. “The phosphoric sun.”

THE DESTRUCTIVE AGENT OF THE AIR.—O is the active principle of the atmosphere. It is destructive in all its effects. Comprising one-fifth of common air, it

is all around us, and, like a lurking lion, constantly on the watch for a chance to spring upon and devour something. We gather a basket of luscious peaches, and put them out of the way of the children; but we cannot outreach the slyest pilferer of all—the O—and soon we shall find the fruit covered with the prints of invisible teeth. Black spots appear, and we say they are decaying; it is only the O feasting upon them, and in a month it will devour them; skin and all. To prevent this, we put our fruit in a glass can, heat it to expel the O, seal it up tightly, and then it is safe from this chemical plunderer.

We open the damper of the stove, and the air rushes in. The O immediately attacks the fuel. Each pair of atoms catches up an atom of C between them, and flies off into the air as carbonic acid.—An animal dies. The O is on the alert; and, the instant his victim expires, and sometimes a little sooner, he is so anxious to commence, he begins to remove that which will soon be an offence to all sensitive nostrils.—We accidentally cut a finger, and soon find the unwelcome O tugging away at the quivering nerve beneath.—The keen throb with which an unsuspected hollow in a tooth is revealed to us, announces the entrance of the foe at an unguarded breach.—The HO in the cistern becomes foul and putrid. We uncover it. In rushes the O, picks up every atom of impurity, and drags it to the bottom. The thick sediment we find when we clean it the next summer, shows how faithfully it did its

work.*—We use our writing-fluid, and the words look pale and dejected. In a few hours we return, and all the letters stand out bold and clear. Noiselessly uniting with the iron of the ink, the skilful intruder has not disturbed the most delicate tracery in taking possession.—The blacksmith draws a red-hot iron from his forge. The O seizes the opportunity while the metal is glowing, and bites off great scales of the black oxyd of iron (Fe_3O_4) that fly in every direction.—We wipe our knives and forks, and carefully lay them away; but if we have left on them the least particle of moisture, as HO favors chemical change, the ever-vigilant O will find it.

The compound here formed will be a higher one than that produced at the blacksmith's forge, since a portion of the O which there united with the iron was driven off by the heat. It will be the red oxyd of iron (Fe_2O_3), or common iron-rust, as we see it on stoves and other utensils.

O IN THE HUMAN SYSTEM.—We take the air into our lungs. Every three minutes all the blood in the system makes the tour of the body, and comes to

* "As the vessel sets sail from London, the captain fills the water-casks with water from the river Thames, foul with the sewage of the city, and containing 23 different species of animalcule; yet, in a few days, the O contained in the air dissolved by the HO, will have cleansed it, and the HO will be found sweet and wholesome during the voyage."

the lungs. Now the blood is full of little iron disks, or gas-bags. These, when old, assume a tawny hue, like the decayed leaves of autumn, shrivel up and die, millions of them perishing at every breath we draw. But when young and vigorous, they take up the O and carry it to all parts of the body, depositing it wherever it is needed. Here the O revels in high life. It sweeps tingling through every artery and vein, distends each capillary tube, sends the quick flush to the cheek, snatches up its portion of the food that comes out of the stomach, gnaws away at the nerves and tissues, eats up every worn-out muscle and all waste matter, until at last it comes back through the veins black and thick with the products of its toil—the cinders of the fire within us.

COMBUSTION AND HEAT.—All processes of fermentation, of decay, of putrefaction, of fire, are called by the chemist, by one name—combustion, or oxidation. They are simply produced by the union of O with the substance. They differ only in the time employed in the operation. If O unites rapidly, we call it fire; if slowly, decay. Yet the process and the products are the same. A stick of wood is burned in my stove, and another rots in the woods, and the chemical change is identical. In the combustion of an atom of O, a certain amount of heat is liberated. Hence, the house that decays in twenty years, gives out as much heat during that time as if it had been swept off in a fierce conflagration in as many minutes.

THE HUMAN FURNACE.—The body is a stove in which fuel is burned, and the chemical action is precisely like that in any other stove. This combustion liberates heat, and our bodies are kept warm by the constant fire within us. We thus see why we fortify ourselves against a cold day by an extra full meal. When there is plenty of fuel in our human furnaces, the O burns that; but if there be a deficiency, the destructive O must still unite with something, so it gnaws away at our flesh;—first the fat, and the man grows poor; then the muscles, and he grows weak; finally the brain, and he becomes crazed. He has simply burned up, as a candle burns out to darkness.

O PRODUCES MOTION.—The action of O in the movement of the muscles is very singular. In order to move a limb, the muscle must contract. So the O unites with a part of the muscle, destroys its structure, and so shortens it. Thus every movement of a limb, every wink of the eye, even, is performed by the disintegration of the muscle used. The truth of this is shown very clearly when we remember that, as soon as we begin to perform any unusual exercise, we commence breathing more rapidly,—showing that we need more O to unite with the muscles to perform the work. In very violent labor, as in running, we are compelled to open our mouths, and take in great swallows of oxygen. This roaring fire within elevates the temperature of the body, and we say “we are so warm that we pant.” Really it is

the reverse. The panting is the cause of our warmth. We need O, then, not only to keep us warm, but also to do all our work. Cut off its supply, and we grow cold, the heart struggles spasmodically for an instant, but the motive power is gone, and the wheels of life soon stand still.*

THE BURNING OF THE BODY BY O.—A man weighing 150 lbs. has 64 lbs. of muscle. This would be burned in about 80 days of ordinary labor. As the heart works day and night, it burns out in about a month. So that we have a literal “new heart” every thirty days. We thus dissolve, melt away in time, and only the shadow of our bodies can be called our own. They are like the flame of a lamp, which appears for a long time the same, since it is “ceaselessly fed as it ceaselessly melts away.” The rapidity of this change in our bodies is remarkable. Says Dr. Draper: “Let a man abstain from water and

* During sleep, the organs of the body are mostly at rest, except the heart. To produce this small muscular exertion very little O is required. As our respiration is, therefore, slight, our pulse sinks, the heat of our body falls, and we need much additional clothing to keep warm. Animals that hibernate show the same truth. The marmot, for instance, in summer is warm-blooded; in the winter its pulse sinks from 140 to 4, and its heat corresponds. The bear goes to his cave in the fall, fat and plump; in the spring he comes out lean and lank. Cold-blooded animals have very inferior breathing apparatus. A snake, for example, has to swallow air by mouthfuls, as we do water. Others have no lungs at all, and breathe in a little air through their skin, enough to barely exist. Is it strange they are cold-blooded?

food an hour, and the balance will prove he has become lighter." At night a person is not quite so tall as in the morning. A French physiologist says his son lost an inch by a single night's dancing. This action of O, so destructive—wasting us away constantly from birth to death—is yet essential to our existence. Why is this? Here is the glorious paradox of life. *We live only as we die.* The moment we cease dying, we cease living. All our life is produced by the destruction of our bodies. Hence the necessity for food to supply the constant waste of our system, and for sleep to give nature time to repair the losses of the day. Thus, also, we see why we feel exhausted at night and refreshed in the morning.

O THE COMMON SCAVENGER.—God has no idlers in his world. Each atom has its use. There is not an extra particle in the entire universe. So the O collects every waste substance, picks up every straggler, and returns it to the common stock, for use in nature's laboratory. In performing this task, its mission is most important and necessary. It sweetens water, it keeps the avenues of the body open and unclogged, it preserves the air wholesome. Oxygen is, in a word, the universal scavenger of nature. No matter can hide away from its keen eye. Every dark cellar of the city, every recess of the body, every nook and cranny of creation, finds it waiting; and the instant an atom is exposed, the oxygen pounces upon it. A leaf falls, and the O forthwith commences

its destruction. A tiny twig, far out at the end of a limb, dies, and the O immediately begins its removal. A pile of decaying vegetables, a heap of rubbish, the dead body of an animal, a fallen tree, even the houses we erect for our shelter the very instant they are built, all are gnawed upon by what we call the "insatiate tooth of time." It is only the constant corrosion of this destructive agent—oxygen.

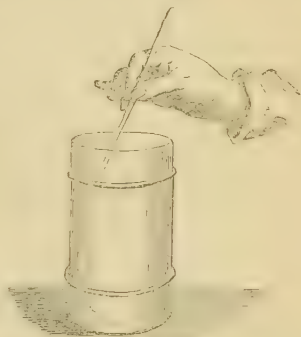
ACTION OF PURE O IN THE BODY.—The action of undiluted oxygen on the animal system is exhilarating in the highest degree. A rabbit immersed in a receiver of this gas soon feels its effect, bounds off into a delirium of excitement, and in a few hours by this quick combustion burns out its little lamp of life. Pure oxygen has been administered in cases of apparent death by drowning. Were it convenient to obtain, it would doubtless be a most excellent restorative. Were we to breathe undiluted oxygen, the veins would presently dilate with the increasing tide of blood, then the eyes would glisten and glare, the gestures become quick and startling, and, if the inhalation of the gas still continued, fever, and, at last, death would ensue.

RESULTS IF THE AIR WERE PURE O.—Were the air pure O, the fire element would run riot everywhere. Our lamps would burn with the oil they contain. Our stoves would blaze with a shower of sparks. A fire once kindled would spread with ungovernable velocity. In a conflagration, not only would the

timber of a house burn, but the nails, the foundation, and even the very water poured upon it to extinguish the flames.

OZONE.—Ozone is an *allotropic* form of O—*i. e.*, a form in which the element itself is so changed as to have new properties. It is always perceived during the working of an electric machine, and is then called “the electric smell.” It has also been detected near objects just struck by lightning. The electricity of the atmosphere is supposed to have something to do with its formation. Its test is a paper wet with a mixture of starch and iodide of potassium (KI). The ozone sets free the iodine, and that unites with the starch, forming the blue iodide of starch. Its identity with O is easily shown. Ex-

ample: Pour a little ether into a jar of common air, and stir in its vapor a heated glass rod. The O will be immediately changed into its allotropic form—ozone, which can be recognized by its pungent odor and the test just named. If the ozone be afterward passed



Making ozone.

through a red-hot tube, it will come out the original O. Ozone is much more corrosive even than oxygen. It bleaches powerfully, and is a rapid disinfectant. A piece of tainted meat plunged into a jar of ozone

is instantly purified. Its abundance in the air produces influenzas, diseases of the lungs, etc.; its absence, fevers, agues, etc.

NITROGEN.

Symbol, N Equivalent, 14 Specific Gravity, 0.97.

This gas is called nitrogen because it exists in **nitre**.

Sources.—Nitrogen is found largely in ammonia and nitric acid. It forms $\frac{1}{3}$ of dried flesh, $\frac{1}{3}$ of the atmosphere, and exists abundantly in mushrooms, mustard, cabbage, horse-radish, turnips, etc. The peculiar odor of burnt hair or woollen is given by the N compounds they contain.

Preparation.—It is prepared by putting in the centre of a deep dish of water a little stand several inches in height, on which a bit of phosphorus may

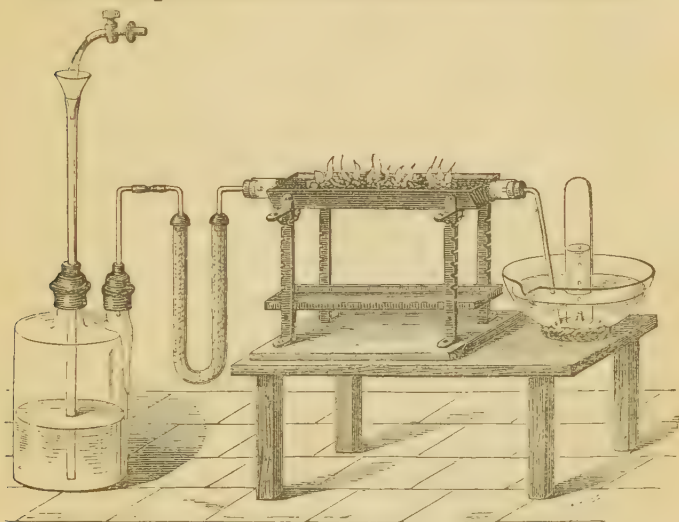


Making nitrogen.

be laid and ignited. As the fumes of phosphoric acid ascend, invert a receiver over the stand. The phosphorus will consume all the O of the air contained in the jar, leaving the N. As the water in the plate rises, add more as needed. It should occupy $\frac{1}{3}$ of the receiver. The jar will at first be filled with white fumes (PO_5), but the water in a few minutes will absorb these.

Another Method.—Nitrogen may also be prepared in large quantities in the manner shown in the

illustration. At the left is a stream of water which falls through a funnel tube into a "Woulfe's bottle." The U-shaped tube is filled with bits of chloride of



Making nitrogen.

calcium to absorb the moisture; and a second tube should be added, filled with pumice-stone, moistened with caustic potash, to deprive the air of its carbonic acid. The long tube is filled with copper turnings, heated by the furnace-fire. The air from the bottle is driven by the falling water up through the U tubes, where it loses its water and carbonic acid; thence among the red-hot copper-turnings, which unite with its O: after which the N, deprived of all its companions, bubbles up through the water into the receiver.

Properties.—All descriptions of nitrogen are of a negative character. It neither burns nor permits anything else to burn. It neither supports life nor destroys it. Yet a candle will not burn in it, and a person cannot breathe it alone and live, simply because it shuts off the life-giving oxygen. So will a person drown in HO, not that the water poisons him, but because it fills his mouth, and shuts out the air. N does not unite with any of the metals. *The instability of all its compounds is its striking peculiarity.* For instance, it may be induced to join its fortune with iodine, but so gingerly, that if we even tread heavily in the room where it is kept, it will leave its partner in high dudgeon, and bound off into the air with a tremendous explosion.

Uses. RELATION OF N TO ORGANIC SUBSTANCES.—Four-fifths of each breath that enters our lungs is N; yet it comes out as it went in, leaving the remaining fifth, O, to perform its wonderful mission within our bodies. One-fifth of our flesh is N, yet none of it comes from the air we breathe. We obtain all our supply from the lean meat and vegetables we eat. Plants breathe the air through the leaves—their lungs; yet they do not appropriate any of the N obtained in this way, but rely upon the ammonia and nitric acid their roots absorb from the soil. N enters the stove with the O: the latter unites with the fuel; but the former, disdaining any such work, passes on out of the chimney. Even from a blast-furnace, where iron instantly melts like wax, the N

comes forth without the smell of fire upon it. So unsocial is it, that it will not affiliate directly with any organic substance. We must all, animals and plants, depend upon finding it bound hand and foot in some chemical compound, and so appropriate it to our use. But even then we hold it very loosely indeed. The tendency of flesh to decompose is mainly owing to the instability of the N in its composition.

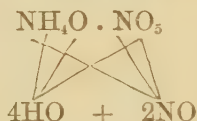
DIFFERENCE BETWEEN N AND O. —We see now how different N is from O. The one is the conservative element, the other the radical. But notice the nice planning shown in the adaptation of the two to our wants. O, alone, is too active, and must be restrained. Were the air pure O, our life would be excited to a pitch of which we can scarcely dream, and would sweep through its feverish, burning course in a few days. Four parts of the negative N just restrain the O within governable limits, adapt it to our needs, and make it our useful servant.

O AND N COMBINED. —Separately, either element of the atmosphere would kill us. The fiery O and the inert N combined give us the golden mean. The O now quietly burns the fuel in our stoves and keeps us warm; licks up the oil in our lamps and gives us light; corrodes our bodies and gives us strength; cleanses the air and keeps it fresh and invigorating; sweetens foul water and makes it wholesome; works all around and within us a constant miracle, yet with such delicacy and quietness that we never perceive or think of it until we see it by the eye of science.

In connection with the above statements concerning N, it is well to remark that late investigators hold that when the stomach is empty a portion of the N from the air is absorbed.

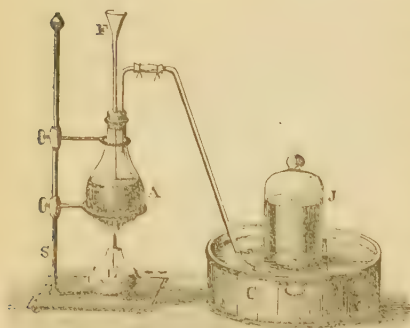
NITROUS OXYD, NO—LAUGHING GAS.

Preparation.—This gas is made by heating nitrate of ammonia. The reaction is as follows: (see p.114)



The atom of N and two atoms of O from the nitric

acid unite with the atom of N from the ammonia, forming 2NO. The four atoms of H in the ammonia unite with three atoms of O in the nitric acid and the one atom of O in the ammonia, forming 4 molecules of HO.



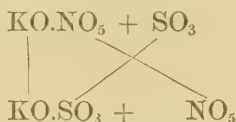
Making NO.

Properties.—It supports combustion almost equally with O, and, like it, is colorless and odorless. It

is soluble in HO, and liquefies at 45° F., with a pressure of 50 atmospheres. It has a sweet taste, and is chiefly noted for its anæsthetic properties.

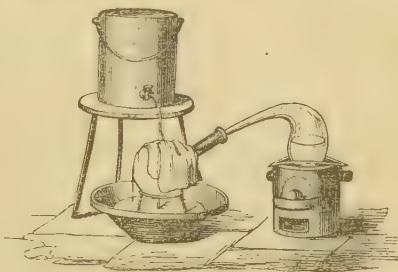
NITRIC ACID (AQUAFORTIS), NO_5 .

This acid is found in nature, in combination with soda or potash, and is obtained in a separate state by the addition of a stronger acid, which drives off the weaker and usurps its place. Thus, taking KO.NO_5 , and adding SO_3 , the following chemical change ensues, while the acid is collected in a receiver, cooled by dropping water :



It is formed in small quantities in the atmosphere by the union of its elements during the passage of electricity, as in a thunder-storm, and being washed to the earth by rain, is absorbed by the roots of plants.

Properties.—It is an intensely corrosive, poisonous liquid. When pure, it is colorless, but as sold,



Making NO_5

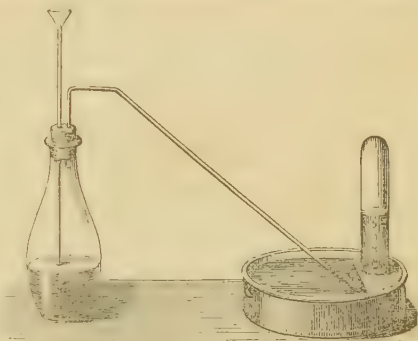
has commonly a golden color, from the presence of the red fumes of nitrous acid, produced by the decomposing action of the light. It has been obtained in the form of brilliant transparent crystals, but is always found dissolved in HO , sometimes of twice its own weight, never less than $\frac{1}{4}$. In strength, it is next to SO_3 . It stains the skin, wood, etc., a bright yellow.

Uses.—It gives up its O very readily, and thus corrodes any substance with which O will combine. It is employed in dyeing woollen yellow, and in surgery for cauterizing the flesh. It dissolves most of the metals, and in combination with HCl forms aqua-regia, a common solvent of gold. It etches the lines in copperplate engraving, and the beautiful designs on the blades of razors, swords, and other steel utensils. The process is very simple. The surface is covered with a varnish impervious to NO_3 ; the desired figure is then sketched in the varnish with a needle. The NO_3 being poured on, oxydizes the metal in the delicate lines thus laid bare.

ACTION ON THE METALS.—If a bit of Sn be placed in NO_3 , the acid will immediately give up to it three atoms of its O , making the metal an oxyd (SnO_2), and reducing itself by the operation to NO_2 (nitric oxyd); this passes off into the air as a gas, and eagerly seizing upon two atoms of O in the air, becomes NO_4 (nitrous acid), which we readily recognize by its brilliant, red-colored fumes. If, instead of the Sn , Cu be used, the action is somewhat different. A

portion of the acid unites with the Cu, forming an oxyd (CuO); but another portion instantly combines with CuO , making $\text{CuO}.\text{NO}_3$. This we detect by the deep blue color it gives to the liquid. If we now evaporate the HO from this solution, we shall obtain beautiful blue crystals of the salt.

The experiment may be performed with the apparatus shown in the cut. The nitric

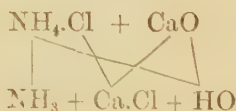


Making NO_2

oxyd, NO_2 , caught in the receiver, will be found colorless, while, on admitting a bubble of air, blood-red fumes of NO_4 will fill the jar.

AMMONIA, NH_3 .—This gas is also called hartshorn, because in England it was formerly made from the horns of the hart. It received the name *ammonia*, by which it is now more generally known, from the temple of Jupiter Ammon, near which sal-ammoniac, one of its compounds, was once manufactured. The *ex-pur-ammonia* of the shops, which is merely a strong solution of the gas in HO , is obtained from the incidental products of the gas-works in large quantities. Water absorbs from 400 to 500 times its own bulk of ammonia. When undiluted, it will produce

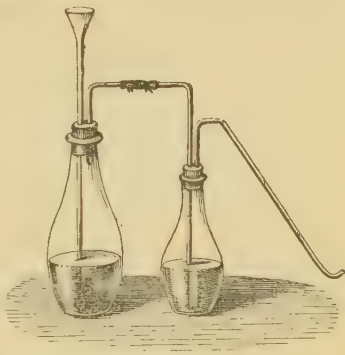
a blister, and should, therefore, be very much weakened before being tasted or touched. It is a strong alkali, and turns the vegetable blues to greens; but owing to its volatility this change of color is only temporary. It is, therefore, sometimes termed "the volatile alkali." Its test is hydrochloric acid, HCl . Example: If we bring a stopple wet with HCl near this gas, it will instantly reveal itself by a dense cloud of white fumes, the chloride of ammonium, sal-ammoniac, which floats in the air like smoke. The antidote of ammonia is vinegar. Its pungent odor can always be detected near decaying vegetable or animal matter. Smelling-bottles are filled with a mixture of finely powdered sal-ammoniac and lime. By this method, ammonia is also made in the arts. The process is hastened by applying heat. The reaction is as follows:



One atom of H of the sal-ammoniac unites with the O of the lime, forming HO. The calcium of the lime combines with the chlorine, producing chloride of calcium, and the NH_3 is set free as a gas which may be absorbed by water, as in the adjoining illustration, thus forming aqua-ammonia.

Nascent state.—If N and H, the elements of NH_3 , be mixed in a receiver, they will not unite chem-

ically, owing to the negative character of N, of which we have before spoken. When, however, any substance is decomposed which contains both of them, as bituminous coal, flesh, etc., at the very instant of their separation from their compounds, in the first feeling of their loneliness, as it were, they will combine and form NH_3 . At this moment,

Making NH_3

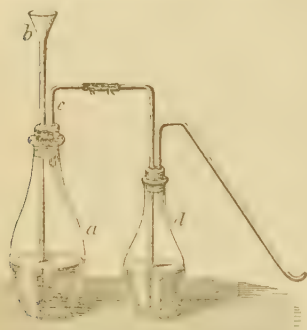
when elements are in the act of leaving their compounds, they are said to be in their "nascent state."

CHLORIDE OF AMMONIUM, MURIATE OF AMMONIA, SAL-AMMONIAC, NH_4Cl .—In the ammoniacal liquors just named, and in the distillation of horns, hoofs, horse-flesh, woollen rags, etc., carbonate of ammonia is formed. By mixing this with HCl , that acid drives off the CO_2 , and takes its place, thus producing chloride of ammonium. On evaporating the solution, tough, fibrous crystals are obtained. They reveal no trace of the pungent ammonia, yet it can be easily set free, as we have already seen. Sal-ammoniac is soluble in HO ; is used in medicine, and also in soldering, the HCl it contains dissolving the coating of the oxyd of the metal, and preserving the surfaces clear for the action of the solder.

HYDROGEN.

Symbol, H Equivalent, 1 Specific Gravity, .069.

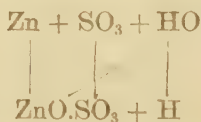
Hydrogen means literally a generator of water.



Making Hydrogen.

Preparation.—It is always obtained by the decomposition of HO, of which it forms $\frac{1}{8}$ part by weight. If we place in an evolution flask (a common junk bottle will answer) bits of zinc, and then pour through the funnel tube sulphuric acid (SO_3) and HO, the

gas will be evolved abundantly. The reaction is as follows :



The zinc decomposes the HO uniting with the O, forming ZnO, and setting free the H, which passes off as a gas. But the ZnO would soon form a coating over the metal, and protect it from the HO ; this the SO_3 prevents by combining with the ZnO, forming $\text{ZnO} \cdot \text{SO}_3$ (white vitriol), and so keeping the surface of the zinc bright and the action constant. The

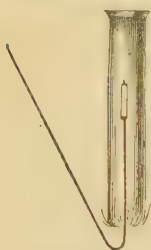
black specks which appear floating about in the solution are charcoal from the Zn. The white vitriol which is formed soon gives the mixture a milky-white appearance. By evaporating the HO, the crystals of this salt can be obtained.

Properties.—H prepared in this manner has a disagreeable odor, from various impurities in the materials used. When pure, like O, it is colorless, transparent, and odorless. Its atoms are the smallest of any known element; and in attempts made to liquefy the gas, it leaked through the pores of the thick iron cylinders in which it was compressed. It is the lightest of all bodies, being only $\frac{1}{14}$ as heavy as common air. It is not poisonous, although, like N, it will destroy life or combustion by shutting out the life-sustainer, O. When inhaled, it gives the voice a ludicrously shrill tone. It can be breathed for a few moments with impunity, if it be first passed through lime-water to purify it. Owing to its lightness, it passes out of the lungs again directly. Its levity suggested its use for filling balloons, and it has been used for that purpose;* but coal gas, which contains much H, and is cheaper, is now preferred.

COMBUSTION OF H.—A lighted candle, plunged into

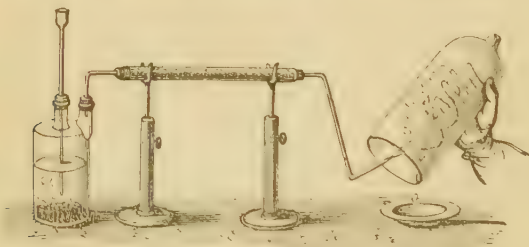
* We read, in accounts of fêtes at Paris, of balloons ingeniously made to represent various animals, so that aerial hunts are devised. The animals, however, persistently insist upon ascending with their legs up—a circumstance productive of great mirth in the crowd of spectators.

an inverted jar of this gas, is extinguished, while the gas itself takes fire, and burns with a pale blue flame. One atom of the O of the air unites with an atom of the H, and the product of the combustion is HO, which may be condensed on a cold tumbler, held over a jet of the burning gas, as in the accompanying figure.



Candle in H.

Mixed Gases.—A mixture of two parts, by measure, of H, with one part of O, or five parts of common air, will explode with a deafening report. The bulky gases being instantly condensed into a mere drop of HO, only $\frac{1}{1700}$ as large, a vacuum is produced, and the



Burning H.

particles of air rushing in to fill the empty space, by their collision against each other, produce the stunning sound. While the detonation is so great, the force is slight, as may be shown by exploding the bubbles in the hand. The two gases may be mingled in the right proportion and kept for years, and there

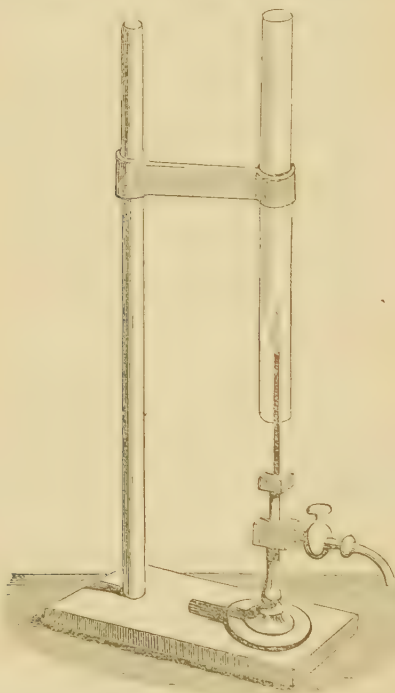
will be no change. The atoms lie against each other quietly, "cheek-by-jowl," without any manifestation of their chemical affinity, when suddenly, at the contact of the merest spark of fire, they rush together with a crash of thunder, and uniting, form the bland, passive liquid—water.

ACTION OF PLATINUM SPONGE.—A piece of platinum sponge placed in a jet of H will ignite it. This curious effect seems to be produced in the following way: The atoms of H and the O of the air are brought so closely together in its minute pores that they unite, and the heat thus produced sets fire to the gas.

HYDROGEN TONES.*—A singular illustration of the laws of sound can be given by simply holding a long glass tube, by means of a suitable clamp, over a minute jet of burning H. At first no effect will be produced; but as we slowly introduce the jet further and further into the tube, a faint sound is heard, apparently

* Another illustration of singing hydrogen may be represented in the following manner: Make a jar of heavy tin, in the form of a double cone, 12 inches long and 4 inches in diameter. At one apex fit a nozzle and cork, at the other, make several minute openings. Covering these openings with sealing-wax, and drawing the cork, fill the jar with H, and replace the cork. When ready for use, hold the jar in a vertical position, remove the wax from at least one orifice, ignite the H at that point, and draw the cork. Still hold the jar quietly, and in a minute or two the tiny jet of H will begin to sing like a swarm of mosquitoes, buzzing and humming in the most aggravating way until, most unexpectedly, the scientific music ends in a loud explosion.

in the far-off distance. This gradually approaches, and finally bursts into a shrill, continuous, musical note—the key-note of the heated column of air within the tube. The cause of this is thought to be



Hydrogen Tones.

that the flame is momentarily extinguished and re-lighted with a slight explosion, which, rapidly repeated, produces the musical note. Indeed, these explosions may be made so slow that the quivering

of the flame can be seen, and the sound cease to be continuous as before. Let us now place the tube at a point where no clapping of hands or unusual sound will start it into song. Let various tones be produced from a violin, and we shall find the flame responding only to that tone which is the key-note of the tube, or its octave. The violin player will have perfect control of this scientific music, and can start, stop, or throw it into violent convulsions, even across a large hall. Tubes of different sizes and lengths will give tones of diverse character and pitch. The waves of sound from the instrument augmenting or interfering with those in the tube probably produce these phenomena.

WATER.

Symbol, HO.....Equivalent, 9.....Freezes at 32°F.....Boils at 212°F.

The composition of HO is proved by analysis and synthesis—*i. e.*, by separating the compound into its elements, and by combining the elements to produce the compound. We can analyze it in the manner already shown in preparing H, or by passing through it a galvanic current, when the O will appear in bubbles of gas at the positive pole, and the H in a similar way at the negative. In the synthetic method, we mix the two gases, and unite them as we have before by an electric spark. The blacksmith decomposes water when he sprinkles it on the hot coals in his forge. The H burns with a blue flame, while the

O increases the combustion. Thus, in a fire, if the engines throw on too little water, it will be decomposed, and so add to the fury of the flame. To "set the North River on fire" is only a poetical exaggeration.

The quantity of electricity required to decompose a single grain of water is estimated to be equal to a powerful flash of lightning. The enormous force necessary to tear these two elements from each other shows the wonderful strength of chemical attraction. We thus see, that in a tiny drop of dew there slumbers the latent power of a thunderbolt.

WATER IN THE ANIMAL WORLD.—The abundance of water very forcibly attracts the attention. It constitutes four-fifths of our flesh and blood. Man has been facetiously described as 12 lbs. of solid matter wet up in six pails of water. All plumpness of flesh, and fairness of the cheek, are given by the juices of the system. A few ounces of water cause the physical difference between the round, rosy face of sixteen, and the wrinkled, withered features of three-score and ten. Our tears, poetical as they may seem to us sometimes, are only water and a pinch of salt. To supply the wants of the system each man needs about $\frac{3}{4}$ of a ton annually. When we pass to lower orders of animals, we find this liquid still more abundant. Sunfishes are little more than organized water. Professor Agassiz analyzed one found off the coast of Massachusetts, which weighed 30 lbs., and obtained only $\frac{1}{3}$ an ounce of dried flesh. Indeed,

naturalists state that an entire order of animals (acelephs), belonging to which are the jelly-fish, medusa, etc., is composed of only ten parts in a thousand of solid matter.

WATER IN THE VEGETABLE WORLD.—In the vegetable world we find it abundant. Wood is composed of 12 parts charcoal and 10 parts water, with a little mineral matter comprising the ashes. Bread is half water; and of the potatoes and turnips cooked for our dinner, it comprises 75 parts of one and 90 of the other. The following table shows the proportion in common vegetables, fruits, and meats:

Mutton....	.71	Trout.....	.81	Cabbage....	.92
Beef	.74	Apples....	.80	Cucumbers .	.97
Veal	.75	Carrots ...	.83	Watermelons	.98
Pork	.76	Beets	.88		

In all these instances water is essential to the structure and constitution of the various substances. Remove it, and they are decomposed into entirely new compounds.

WATER IN THE MINERAL WORLD.—Here we find a class of bodies in which the water is chemically combined in definite proportions. Such are called *hydrates*. In the image which the Italian pedler carries through our streets for sale, there is 1 lb. of HO to every 4 lbs. of plaster of Paris. One-third of the weight of the soil of our farms is this same liquid. Each pound of strong NO_3 contains $2\frac{1}{4}$ oz. of water, which, if removed, would destroy the acid

itself. If we expel the water from oil of vitriol, it will lose its acid properties, and we can handle it with impunity. In bodies which are capable of crystallizing, it seems only to determine the form and general appearance, and is called "the water of crystallization." If we evaporate this from blue vitriol, it will lose its color and become white like flour. A few drops of HO will restore the blue. If we expel it from alum, it will puff up, and the transparent crystals will dry into an incoherent mass. Water of crystallization gives all the transparency to the opal, which else would be only common flint-stone.

WATER AS A SOLVENT.—Water, having no taste, color, or odor itself, is perfectly adapted to become the universal solvent, receiving instantly the characteristics of any substance placed in it. It becomes at pleasure sweet, sour, salt, bitter, nauseous, and even poisonous. Had water any taste, the whole science of cookery would be changed, since each substance would partake of the one universal watery flavor.

PURE WATER.—Rain-water, caught after the air is thoroughly cleansed by previous showers, and at a distance from the smoke of cities, is the purest natural water known. This is tasteless, yet its insipidity makes it seem to us very ill-flavored indeed. We have become so accustomed to the taste of the impurities in hard water, that they have become to us tests of its sweetness and pleasantness.

HARD WATER.—As water filters down through the

soil into our wells, it dissolves the various mineral matters characteristic of the locality. The most common of these are lime, salt, and magnesia. The former produces a *fur* or coating on the bottom of our teakettles, if we live in a limestone region. When we put soap in such water, it curdles—*i. e.*, it unites with the lime, forming a new or lime soap, which is insoluble in HO.

SEA-WATER.—Common salt is the most abundant mineral in the ocean. Yet it contains traces of every substance soluble in water, which has been washed into the sea from the surface of the continents during all the ages of the past. Its saline constituents are now in the proportion of about a $\frac{1}{2}$ oz. to a lb., which amount must be slowly increasing, as the water which evaporates from the surface is comparatively pure, containing only a mere trace of a few substances, which give to the sea-breeze its peculiar bracing, tonic influence. In this way, the water of the Salt Lake has become the strongest of brine, nearly one-third of its whole weight consisting of saline matter. This condition would soon disappear if an outlet could be provided.

WATER ATMOSPHERE.—As the world of waters is inhabited, it has its atmosphere also.* Inasmuch as the HO dilutes the O in part, it does not need so

* Fish breathe O through the fine silky filaments of their gills. When a fish is drawn out of H₂O, these dry up, and he is unable to breathe, although he is in a more plentiful atmosphere than he is accustomed to enjoy.

much N as the common air. It is accordingly composed of $\frac{1}{3}$ O instead of $\frac{1}{5}$. The air so rich in O thus absorbed by the water gives it its life and briskness. If it be expelled by boiling, the water tastes flat and insipid.

PARADOXES OF HO.—“Cold contracts,” is the law of physics; but as HO cools, it obeys this principle only as far as 39° F. Then it slowly expands, cooling down to 32° , its freezing point, when its crystals suddenly dart out at angles to each other, and thus, increasing its size $\frac{1}{10}$, it congeals to ice. By this wise exception, ice is lighter than HO, and so swims on top; otherwise our rivers would freeze solid, killing the fish and aquatic plants. The longest summer could not melt such an immense mass of ice. But now the blanket that nature kindly weaves over the rivers and ponds keeps their finny inhabitants warm and comfortable till spring; then she floats it south to melt under a hotter sun. We give to water such contradictory terms as hard water and soft water, fresh water and salt water. Water seems the most yielding of substances, yet the swimmer who falls on his face instead of striking head foremost understands the mistake, and we could drive a nail into a *solid* cube of steel easier than into a *hollow* one perfectly filled with HO. H is the lightest substance known, and O is an invisible gas; yet they unite and form a liquid whose weight we have often experienced, and a solid which makes a pavement as hard and unyielding as granite. H burns readily and explodes

most fearfully, O supports combustion brilliantly—yet the two combined are used to extinguish fires. Hydrogen or oxygen in excess would destroy life ; water is so essential to it that thirst causes a lingering, painful death.

USES OF WATER.—The uses of water are as poetical as they are practical. Its properties fit it for a wonderful variety of operations in nature. Its office is not merely to moisten our lips on a hot day, to make a cup of strong tea, to lay the dust in the street, and to sprinkle our gardens. It has grander and more profound uses than any of these. *Water is the common carrier of creation.* It dissolves the elements of the soil, and climbing as sap up through the delicate capillary pump of the plant, furnishes the leaf with the materials of its growth. It flows through the body as blood, floating to every part of the system the life-sustaining O, and the food necessary for repairs and for building up the various parts of the “house we live in.” It comes in the clouds as rain, bringing to us the heat of the tropics, and tempering our northern climate, while in spring it floats the ice of our rivers and lakes away to warmer seas to be melted. It washes down the mountain side, levelling its lofty summit and bearing mineral matter to fertilize the valley beneath. It propels water-wheels working forges and mills, and thus becomes the grand motive-power of the arts and manufactures. It flows to the sea, bearing on its bosom ships conducting the com-

merce of the world. It passes through the arid sands, and the desert forthwith buds and blossoms as the rose. It limits the bounds of fertility, decides the founding of cities, and directs the flow of trade and wealth.

CARBON.

Symbol, C Equivalent, 6.

Carbon is one of the most abundant substances in nature, forming nearly one-half of the entire vegetable kingdom, and being a prominent constituent of limestone, corals, marble, magnesian rocks, etc. We find it in three distinct forms or allotropic conditions—viz., the *diamond*, *graphite*, and *amorphous carbon*. This last term means without form or crystals, and includes gas-carbon, charcoal, lamp-black, coal, coke, peat, soot, bone-black and ivory-black. In each of these various substances C possesses different properties; yet any impurities it may contain seem entirely incidental, and not at all necessary to its new state.

PROOF OF THIS ALLOTROPIC STATE.—Chemists have changed most of these substances into other allotropic forms. Thus, common charcoal has been turned into graphite, mineral coal into gas-carbon, the diamond into coke. All of them, when heated in the open air, unite with the same quantity of O, forming precisely the same compound—carbonic acid gas—from which the carbon can be obtained again in the form of charcoal.

THE DIAMOND is *pure carbon* crystallized. It is the hardest of all known substances, scratches all other minerals and gems, and can be cut only by its own dust. It is infusible, but will burn at a high temperature. It is found in various parts of the world—North Carolina, Georgia, Borneo, and Brazil. The ancient mines of Golconda, in Hindostan, are not now worked. In 1858, Brazil furnished 120,000 carats.* Diamonds are supposed to be of vegetable origin, and to have exuded, at some past time, as gum does now from cherry-trees, and then slowly crystallized into octahedrons and other forms. They are often found covered with a crust, which being broken reveals the brilliant gem within. They are of various colors, though often colorless and perfectly transparent. The latter are most highly esteemed, and, from their resemblance to a drop of clear spring-water, are called diamonds of the “first water.”

THE DIAMOND IS GROUND by means of its own powder. Being fitted to the end of a stick or handle, it is pressed down firmly against the face of a rapidly revolving wheel, covered with diamond-dust and oil. This, by its friction, removes the exposed edge and forms a *facet* of the gem. There are three forms of cutting—the *brilliant*,



The brilliant.



The rose.

* A carat is equal to 4 gr. Troy. The term is derived from the name of a bean which, when dried, was formerly used by diamond merchants in India as weights.

the *rose*, and the *table*. The brilliant has a flat surface on the top, with facets at the side, and with facets below terminating in a point, so arranged as to refract the light most brilliantly. This form shows the stone to the best advantage, but is used only in large, thick stones, as it sacrifices nearly half the weight in cutting. The *rose* is flat beneath, while the upper surface is ground into triangular facets, terminating at a common vertex. The *table* form is used only for thin specimens, which are merely ornamented by small facets on the edge. The diamond is valued not alone for its rarity and high refractive power, by which it flashes such vivid and brilliant colors, but also for its mechanical uses. For cutting glass, the curved edges of the natural crystal are used.

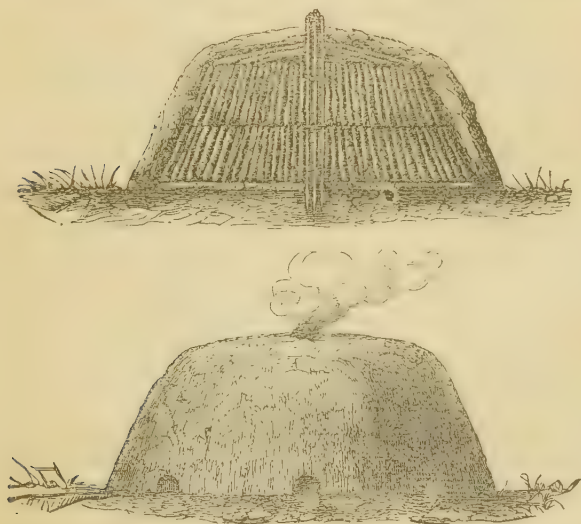
GRAPHITE or PLUMBAGO is also called black-lead, because on paper it makes a shining mark like lead. It is found at Ticonderoga, N. Y., and at Brandon, Vt. It is supposed to be of vegetable origin.

Uses.—It is chiefly useful in pencils. For this purpose a mixture of black-lead, antimony, and sulphur—the proportion of these ingredients determining the hardness of the pencil—is melted and cast into blocks, which are then sawed into thin slips, as seen in common pencils. For drawing-pencils, pure graphite powder is subjected to such enormous pressure that the particles are brought near enough together for the attraction of cohesion to hold them in a solid form, when the pressure is removed. This solid block is then sawed into prisms as before, and fitted into

cylinders of cedar-wood. Though graphite seems very soft, yet its particles are extremely hard, and the saws used in cutting it soon wear out. We notice the same fact in sharpening a pencil with a knife. Graphite mixed with clay is made into black-lead crucibles. These are the most *refractory* known, and are used for melting gold and silver. It is also sold as "British lustre," "carburet of iron," "stove polish," etc., which are employed for blacking stoves and protecting iron from rusting.

GAS-CARBON is formed on the interior of the retorts used in coal-gas works. It has a metallic lustre, and will scratch glass.

CHARCOAL.—This is formed by burning piles of



Making charcoal.

wood, covered over with turf, so as to prevent free access of air. The volatile gases, water, etc., are driven off, and the C left behind. This forms about $\frac{3}{4}$ of the bulk of the wood and $\frac{1}{4}$ its weight. Charcoal for gunpowder and for medicinal purposes is prepared by heating willow or black alder in iron retorts.

Properties.—It is the most unchangeable of all the elements, so that even in the charcoal we can trace all the delicate structure of the plant of which it was made. It is insoluble in any liquid. None of the acids, except nitric, corrodes it. No alkali will eat it. Neither air nor moisture affects it. Wheat has been found in the ruins of Herculaneum that was charred 1800 years ago, and yet the kernels are as perfect as if grown last harvest. The ground ends of posts are rendered durable by charring. Indeed some were dug up not long since in the bed of the Thames which were placed there by the ancient Britons to oppose the passage of Julius Caesar and his army. A cubic inch of fine charcoal has 100 feet of surface, so full is it of minute pores. These absorb gases by capillary attraction to an almost incredible extent. A bit of C will take up 90 times its bulk of ammonia. As the various gases and the O of the air are brought so closely together within its pores, rapid chemical changes are produced, as in the case of platinum black, of which we have already spoken. Fresh provisions are packed in C for long voyages, and hams have been thus kept sweet for years. Foul water filtered through C loses its impurities. Beer

by this process parts not only with its color but with its bitter taste. Ink is robbed of its value and comes out clear and transparent as water.

Deoxygenizing Action of C.—At a high temperature the appetite of C for O is insatiable. It will take it out in the heat of a furnace from almost the stablest compounds. Upon this fact depends its use in the arts. Nearly all the ores and many of the elements are locked up in the rocks with O, and C is the key expressly made by the Creator for unlocking the treasure-houses of nature for the supply of our wants. By noticing the process of preparing zinc, iron, phosphorus, etc., we shall see the importance of this property of C. A very pretty illustration is shown by placing a few grains of litharge (PbO), or the oxyd of any metal, on a flat piece of charcoal, and directing upon it the flame of a blow-pipe. The metal will immediately appear in little sparkling globules.



Litharge on charcoal.

SOOT is unburnt carbon which passes off from a lamp or fire when there is not enough O present to combine with all the C of the fuel. This, therefore, comes away in flakes, and blackens the chimney of the lamp, or lodges in the chimney of the house. After a time it gathers in sufficient quantity, and we are startled by the cry, "The chimney is on fire!" while with a great roar and flame the soot burns out. This unpleasant occurrence is much more frequent when green wood is used for fuel. The HO of the

wood absorbs much of the heat of the fire, and so permits the C to pass off unconsumed.

LAMPBLACK is obtained by imperfectly burning pitch or tar. The dense cloud of smoke is conducted into a chamber lined with sackings, upon which the soot collects. It is largely used in painting. It is mixed with clay to form black drawing-crayons, and with linseed oil to make printers' ink. Lampblack or charcoal has peculiar properties which fit it for printing. Nothing in nature could supply its place. No matter how finely it is pulverized, it retains its dead-black color. The minutest particle is as black as the largest mass. No chemical agents will change it. It never decays. The paper may moulder—we may even burn it, and still, in the ashes, can we trace the form of the printed letter. The ancients used an ink composed of gum-water and lampblack, and manuscripts have been exhumed from the ruins of Pompeii and Herculaneum which are yet perfectly legible.

ANIMAL CHARCOAL, or bone-black, is made by burning bones in close vessels. Mixed with oil of vitriol, it forms paste-blackening. Common vinegar filtered through it becomes the colorless white vinegar of the pickle manufacturers. It is largely used by sugar refiners. Brown sugar is dissolved in HO, and the solution filtered through animal charcoal. This removes all the impurities which constitute the coloring matter. The solution is then slowly evaporated in "vacuum pans," and the sugar collects in clear white crystals.

MINERAL COAL.—This was formed in a former period of the world's history, called the Carboniferous Era. At that time the world was pervaded by a genial tropical climate. The air was denser and richer with vegetable food than now. The earth itself was a swamp, moist and hot, in which plants that creep at our feet to-day, or are known only as rushes or grasses, grew to the height of lofty trees, and simple ferns towered into trunks a foot and a half in diameter. These fern-forests resounded with no song of bird or hum of insect ; but a strange and grotesque vegetation flourished with more than tropical luxuriance. In these swamps accumulated a vast deposit of leaves and fallen trunks which, under the water, gradually changed to charcoal. In the process of time the earth settled at various points, and floods poured in, bringing sand, pebbles, clay, and mud, filling up all the spaces between the trees that were standing, and even the hollow trunks themselves. The pressure of this soil and the internal heat of the earth combined to expel the gases from the vegetable deposits, and convert them into mineral coal. Where this process was nearly complete, anthracite coal, and where only partially finished, bituminous coal, was formed. The greater the pressure, the harder and purer the carbon produced ; unless, however, the covering was not sufficiently porous to allow the gases to escape, when bituminous coal was the result. In time this section was elevated again, and another forest flourished, to be in its turn

converted into coal. Each of these alternate elevations and depressions produced a layer of coal or of soil. In these beds of coal we now find the trunks of trees, the outlines of trailing vines, the stems and leaves of plants as perfectly preserved as in a herbarium, so that, to the botanist, the flora of the Carboniferous era is as complete as that of our own.

COKE is the refuse of gas-works, obtained by distilling off all the water, tar, and volatile gases from bituminous coal. It is burned in locomotives, blast-furnaces, etc.

PEAT is an accumulation of half-decomposed vegetable matter in swampy places. It is produced mainly by a kind of moss which gradually dies below as it grows above, and thus forms beds of great thickness. Sometimes, however, plants may grow in the form of a turf, and decay, thus collecting a vast amount of vegetable *débris*. This gradually undergoes a change, and becomes a brownish black substance, loose and friable in its texture, resembling coal, but, unlike it, containing 20 to 30 per cent. of O. These peat-beds are of vast extent. One-tenth of Ireland is covered by them. One, near the mouth of the River Loire, is said to be fifty leagues in circumference. In Massachusetts and in New York peat is becoming of commercial value, and is used as a fuel in large quantities. For this purpose it is cut out in square blocks and dried in the sun. In many beds it is first finely pulverized, then pressed into a very compact form like brick.

MUCK is an impure kind of peat, not so fully carbonized, though the term is frequently applied to any black swampy soil which contains a large quantity of decaying vegetable matter. Like charcoal, it absorbs moisture and gases, and is therefore used as a fertilizer.

VARIOUS FORMS AND USES OF CARBON.—We have seen in what contrary forms carbon presents itself. It is soft enough for the pencil-sketch, and hard enough for the glazier's use. Black and opaque, it expresses thought on the printed page: clear and brilliant, it gleams and flashes in the diadem of a king. In lampblack it frequently takes fire spontaneously; in graphite, it resists the heat of the fiercest flame; in the diamond, it is an insulator, while in charcoal, it is so perfect a conductor of electricity, that it is packed about the foot of lightning-rods to complete the connection with the earth. We burn it in our lamps, and it gives us light; we burn it in our stoves, and it gives us heat; we burn it in our engines, and it gives us power; we burn it in our bodies, and it gives us strength. As fuel, it readily unites with O, yet we spread it as stove-polish on our ironware to keep the metal from rusting. It gives firmness to the tree and consistency to our flesh. It is the valuable element of all fuel, burning oils, and gases. Thus it supplies our wants in the most diverse manner, illustrating in every phase the forethought of that Being who fitted up this world as a home for his children. Infinite Wisdom alone would

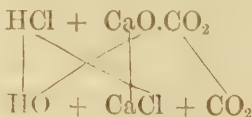
have stored up such supplies of fuel and light, and hidden them far under the earth away from all danger of accidental combustion, or anticipated all the requirements alike of luxury and the arts.

CARBONIC ACID.

Symbol, CO_2 Equivalent, 22 Specific Gravity, 1.52.

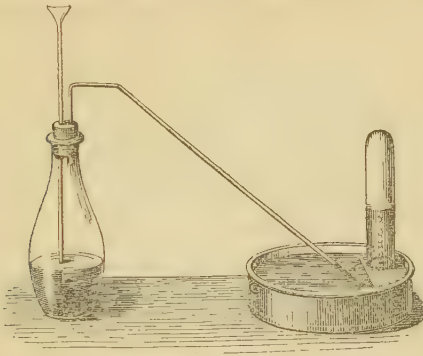
Sources.—It is found combined with lime, as in limestone, marble, chalk, and also in a large class of salts, known as the carbonates, forming nearly one-half of their weight, and almost one-seventh of the crust of the earth. It comprises $\frac{1}{1000}$ part of the atmosphere. It is produced throughout nature in immense quantities. Wherever C burns, in fires, lights, decay, fermentation, volcanoes—in a word, in all these various forms of combustion of which we spoke under the subject of O, where that gas unites with C, carbonic gas is the result. Each adult exhales about 140 gallons per day. Each bushel of charcoal, in burning, produces 2500 gallons.

Preparation.—For experimental purposes it is prepared by pouring HCl (hydrochloric acid) on marble or chalk. The reaction is as follows:



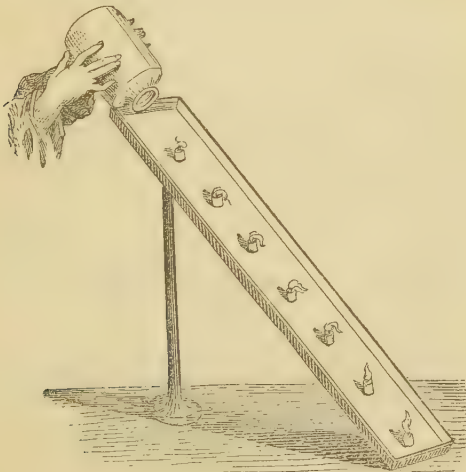
The H of the hydrochloric acid unites with the O of the lime (CaO), forming HO. The Cl of the acid

combines with the Ca of the lime, forming chloride of calcium, while the CO_2 is driven off. It may be



Making carbonic acid.

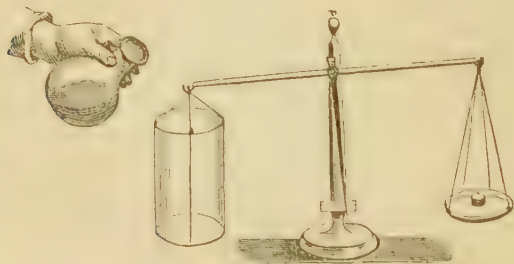
collected in bottles by displacement, or as represented in the cut.



Pouring CO_2 down-hill.

Test.—Its test is clear lime-water. If we expose a saucer of lime-water to the air, its surface is soon covered with a thin pellicle of carbonate of lime, thus showing that there is CO_2 in the atmosphere; or if we breathe by means of a tube through lime-water, the solution will become turbid and milky, thus proving the presence of CO_2 in our breath: by breathing through the liquid a little longer it will become clear, as the carbonate of lime will dissolve in an excess of CO_2 .

Properties.—It is a colorless, odorless, transparent gas, with a slightly acid taste. It is a non-supporter of combustion, will run down an inclined plane, and can be poured from one dish to another be dipped up with a bucket like water, or be weighed in a pair of scales like lead. Example: The accompanying



Weighing CO_2 .

cut shows a very neat way of illustrating several of these properties. For weighing, the CO_2 may be contained in a large paper box or bag, such as is used by grocers.

Poisoning by CO_2 .—This gas is fatal to life (p. 239). Largely diluted it acts as a narcotic, producing languor, and finally insensibility and death. It accumulates in wells and cellars, and many persons have been poisoned by descending into such places incautiously. The test of lowering a lighted candle should



Candle in jar
of CO_2 .

always be employed. If that is extinguished, your life would be in danger of "going out" in the same way, should you descend. The gas may be dipped out like water, or the well may be purified by lowering pans of slacked lime, or lighted coals



A candle in CO_2 .

which, when cool, will absorb the noxious gas. The coals may be reignited, and lowered repeatedly until the result is reached. A well, in which a candle would not burn within 26 feet of the bottom, was thus purified in a single afternoon. Persons have been poisoned by burning charcoal in an open furnace in a closed room. In France, it is not unusual to commit suicide in this manner. The antidote is to bring the sufferer into the fresh air, and dash cold water upon his face. In the celebrated *Grotto del Cane*, in Italy, the gas accumulates near the floor, so that a man living near amuses visitors, for a small fee, by leading his dog into the cave. He experiences no ill effects himself, but the dog soon falls senseless. A dash of cold water revives him, and

he is ready to pick up his bone and enjoy the reward of his scientific experiment. The celebrated Upas tree of Java seems not to be altogether fabulous. The poison is not derived from the tree itself; but is due to the fact that it is located in a deep valley about a half-mile in circumference, in which CO_2 is evolved in quantities sufficient to contaminate the entire atmosphere. The valley is said to be strewn with the bones of animals and birds which have strayed into this gaseous lake.

CO₂ in Mines.—Miners call CO_2 *choke-damp*. It is produced by the explosion of *fire-damp* (light carburetted hydrogen) which accumulates in deep mines, and burns with a shock like gunpowder, forming dense volumes of CO_2 , which instantly destroys the lives of all who may have escaped the flames of the explosion. Where CO_2 alone is found, it is not considered as dangerous as the *fire-damp*, since it will not burn, and it is said that miners will even venture "where the air is so foul that the candles go out, and are then relighted from the flame on the wick by swinging them quickly through the air, when they burn a little while and then go out, and are relighted in the same way." CO_2 has been used for the purpose of extinguishing fires in coal-mines. In one case an English mine had burned for 20 years, consuming a seam of coal over a space of 26 acres, defying all attempts to quench it. 8,000,000 cubic feet of CO_2 were poured into it day and night for three weeks, when the mine was cooled with water; and at last, at the close of

the month, the mine was ready for labor to be resumed.

Absorption of CO₂ by Liquids.—Water dissolves its own volume of CO₂ under the ordinary pressure of the atmosphere; but with increased pressure, it will absorb a much greater amount. “Soda water” is improperly named, as it contains no soda, but is simply water saturated with CO₂ in a copper receiver strong enough to resist the pressure of 10 or 12 atmospheres. This gas gives the HO a pleasant, pungent, and slightly acid taste, and by its escape, when exposed to the air, produces a brisk effervescence. In beer, ginger-pop, cider, wine, etc., the CO₂ is produced by the fermentation going on within. The gas escapes rapidly through cider and wine, and so produces only a sparkling; while in a thick, viscid liquid, like beer, the bubbles are partly confined, and so cause it to foam and froth. In canned fruits, catsup, etc., the souring of the vegetables produces CO₂, which sometimes drives out the cork or bursts the bottles with a loud report, scattering the contents far and wide.

Liquid CO₂.—By a pressure of 40 atmospheres, at a temperature of 32°, CO₂ becomes a colorless liquid, very much like water. When this liquid is brought out into the air, it evaporates so rapidly that a portion is frozen into a snowy solid which burns the flesh like a red-hot iron. By means of solid CO₂, which has a temperature of –150° F., mercury can be frozen even in a red-hot crucible. Mixed with ether,

and evaporated under the exhausted receiver of an air-pump, Professor Faraday obtained a cold of 166° below zero.

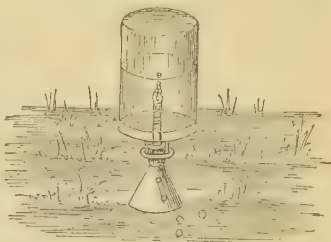
Ventilation.—The relation of carbonic acid to life is most important, and cannot be too often dwelt upon. We exhale constantly this poisonous gas, each person contaminating at least 10 cubic feet of air per minute. If means are not provided to furnish us fresh air constantly, we are compelled to re-breathe that which our lungs have just expelled. The languor and sleepiness we feel in a crowded assembly, are the natural effects of this narcotic poison. The idea of drinking in at every breath the exhalations that load the atmosphere of a crowded, promiscuous assembly, is disgusting as it is noxious. We shun impurity in every form; we dislike to wear the clothes of another, or to eat from the same dish; we shrink from contact with the filthy, and yet sitting in the same room inhale their poisonous breath. Health and cleanliness alike require that we should carefully ventilate all public buildings, our school-rooms, and our sleeping-apartments. Fresh air and good water are the cheapest luxuries of life, and alas! too commonly the rarest.

Singular Truth.—It is a fact, as poetical as it is characteristic, that when the air comes forth from the lungs it is poisonous, fully charged with the seeds of disease, so that if we should re-breathe it, death would inevitably ensue; yet as it passes out it produces all the tones of the human voice, all songs, and

prayers, and social conversation. Thus the gross and deadly is by a divine simplicity made refined and spiritual, and caused to minister to our highest happiness and welfare.

CARBONIC OXYD (CO).—This is a colorless, almost odorless gas. It burns with a pale, blue flame, absorbing an atom of O from the air, and becoming CO_2 . It is seen thus burning in our coal-stoves, and at the top of tall furnace-chimneys. It is caused by an insufficient supply of O . It is a deadly poison, and escaping from coal-fires in a close room has often produced death. The offensive odor which comes out on opening the door of our coal-stoves is caused by the compounds of sulphur mixed with the CO .

LIGHT CARBURETTED HYDROGEN (C_2H_4).—This is the gas we have already spoken of under CO_2 , as the dreaded fire-damp of miners. It is colorless, tasteless, odorless, and burns with a yellowish flame. It is formed in swamps and low marshy places by the decomposition of vegetable matter, and on stirring the mud beneath, will be seen bubbling up through the water. It rises from



the earth in great quantities at many places. At Fredonia, N. Y., it is collected and used in lighting the village. At Kanawha, Va., it is employed as fuel for evaporating the brine in the manufacture of salt.

In the oil-wells of Pennsylvania, it frequently bursts forth with explosive violence, throwing the oil high into the air.

HEAVY CARBURETTED HYDROGEN (C_4H_4).—*Olifiant Gas*.—This is a colorless gas, with a sweet, pleasant odor, and burns with a clear white light.

ILLUMINATING GAS consists principally of the two gases just named. The proportion of the latter, or olefiant gas, which gives the clearness and whiteness to the flame, determines its value. It is made by heating bituminous coal in large iron retorts until coke only is left, and all the volatile constituents are driven off.* These are very numerous. Among them are coal-tar, ammonia, carbonic acid, carbonic oxyd, nitrogen, compounds of sulphur, light and heavy carburetted hydrogen. This mixture is first cooled in the *condenser*, which is a series of iron tubes surrounded by cold water, in which the coal-tar is deposited, with the ammoniacal liquids. Then it is sprinkled with a spray of water, which takes out all the ammonia, and last of all passed through milk of lime, which absorbs the carbonic acid. The remaining gases form the mixture we call "gas." This is then collected in the gasometer, the weight of which forces it through all the little gas-pipes, and up to every jet in the city. Its unpleasant odor, and the danger resulting from its escape in our rooms, are the same we have just mentioned in coal fires.

CYANOGEN (Cy ,— NC_2).—If we mix hides, horns, etc.,

* A ton of Cannel coal will yield 15,000 feet of gas.

with carbonate of potash and iron filings, and heat them in a close vessel, the N and C of these animal substances in their nascent state will combine, forming cyanogen. This unites with the iron and potassium, forming the beautiful yellow crystals of ferrocyanide of potassium, or so-called *yellow prussiate of potash*. The compounds of cyanogen are named cyanides, and are all made from this salt.

HYDROCYANIC ACID (HCy).—Prussic acid, as it is commonly called, is a most fearful poison. A single drop on the tongue of a large dog is said to produce instant death. Ammonia, cautiously inhaled, is its antidote. Its bitter flavor is detected in peach blossoms, the kernels of plums or peaches, bitter almonds, and the leaves of wild cherry.

FULMINIC ACID.—This compound of Cy is known only as combined with the various metals forming fulminates, which are fearfully explosive. (The term *fulminate* is from the Latin *fulmen*, a thunderbolt.) Fulminating mercury was used to fill the bombs with which the life of Napoleon III. was attempted in 1858. It is employed in making gun-caps. A drop of gun is first put in the bottom of the cap, over which is sprinkled a little fulminating mercury, and this is sometimes covered with varnish to protect it from the moisture.

COMBUSTION.

Combustion, in its popular sense, is the union of a substance with O, and includes all the various forms

of oxydation we named when treating of that gas. The amount of heat depends upon the quantity of O which enters into combination.

Example: $\text{HO} = 9$. Hence, in 9 lbs. of HO there are 8 lbs. of O, and 1 lb. of H. On the other hand, $\text{CO}_2 = 22$. Hence, in 22 lbs. of carbonic acid there are 6 lbs. of C and 16 of O; 1 lb. of C unites with $2\frac{2}{3}$ lbs. of O. Therefore, H combines with three times as much O as C does, and so gives off three times as much heat. The intensity of the heat depends upon the rapidity with which the fuel unites with O. So we open the draft, or blow a fire, to furnish this active element of the air in greater abundance.

The Igniting Point.—Although O unites at all temperatures, yet combustion, in its popular sense, does not commence until the heat of the combustible is raised to a certain point, when we say “it has caught fire.” The burning point of any substance is the temperature at which it bursts into quick combustion. We elevate the heat of a small portion to the point of rapid union with O, and that part in burning will give off heat enough to support the combustion of the rest. Example: In making a fire, we take a substance for kindling which unites with O at a low temperature, as paper or shavings, with which we obtain heat enough to start the combustion of something that requires a higher temperature, as chips or pine sticks, and thus gradually increase the degree of heat until we reach the igniting point of

coal or wood. If we pour on much coal when the fire is low, we shall put it out, because the fresh fuel lowers the heat below the point of union with O, which is about 1000° .

CHEMISTRY OF A FIRE.—All our fuel and lights, such as wood, coal, oil, tallow, etc., consist mainly of C and H, and are, therefore, called *hydrocarbons*. In burning, they unite with the O of the air, forming HO and CO₂. These both pass off, the one as a vapor, the other as a gas. In a long stove-pipe, the HO is sometimes condensed, and drips down, bringing soot upon our carpets. Ashes comprise the mineral matter contained in the fuel, united with some of the CO₂ produced in the fire. When we first put fuel in the stove, the H is liberated with some C, in the form of carburetted hydrogen gas. This burns with a flame. Then, the volatile H having passed off, we have left the C, which burns as a coal merely. In maple there is much more C than in pine, so it forms a good “bed of coals.” In the burning of fuel there is no annihilation; but the HO, CO₂, and the ashes, weigh as much as the wood and the O that combined with it. No matter how rapidly the fire burns, in the blaze of the fiercest conflagration, the elements unite in exact chemical equivalents. Carbon is most wisely fitted for fuel, since the product of its combustion is a gas. Were it not so, our fires would be choked, and before each supply of fresh fuel we should be compelled to remove the ashes that filled the stove. In the case of a

candle it would be still more annoying, as the solid product would fall around our rooms in an acid shower that would corrode every thing it touched. Still another property is the infusibility of carbon. Did it melt like zinc or lead on the application of heat, how quickly in a hot fire would the coal and wood melt, and run down through the grate and out upon the floor in a liquid mass! These properties, together with its abundance, exactly adapt it to our use.

CHEMISTRY OF A CANDLE.—Flame is burning gas. A candle is a small “gas-works,” and its flame is the same as that of a “gas-burner.” First we have a

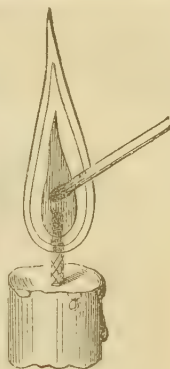


Form of flame.

little cupful of tallow melted by the heat of the fire above. The ascending currents of cool air which supply the light with O also keep the sides of the cup hard, unless the wind blows the flame downward, when the banks break, there is a *crucuse*, and our candle runs down. Next, the melted tallow is carried by capillary attraction up the small tubes of the wick into the flame. There it is turned into gas by the heat. Flame is always hollow, and at the centre, near the wick, is the gas just formed. If a

match be placed across a flame, it will burn off at each side in the ring of the flame, while the centre will be unblackened. The gas may be conducted out of the flame by a small pipe, and burned at a little distance from the candle. The flame is hollow

because there is no O at the centre. The gas floats outward from the wick. It comes in contact with the O of the air, and the H, requiring least heat to unite, burns first, forming HO. This produces heat enough to make the tiny particles of C, floating around in the flame of burning H, white-hot. They each send out a delicate wave of light, and passing on to the outer part, where there is more O, burn, forming CO_2 . The flame is blue at the bottom, because there is so much O at that point that the H and C burn together, and so give little light. The HO may be condensed on any cold surface. The CO_2 may be tested by passing the invisible smoke of a candle through lime-water. The wick of a candle does not burn because of the lack of O at the centre. It, however, is charred, as all the volatile gas is driven off by the heat. If a portion falls over to the outer part, where there is O, it burns as a coal. If we blow out a candle quickly, we can see the gas passing off, and can relight the candle with an ignited match held at some distance from the wick. The tapering form of the flame is due to the currents of air that sweep up from all sides toward it. The candle must be snuffed, because the long wick would cool the blaze below the igniting point of C and O, and the C would pass off unconsumed. A draught of air, or any cold substance thrust into the flame,



Match in flame.

produces the same result, and deposits the C as soot. Plaited wicks are sometimes used, which, being thin, fall over to the outside and burn, requiring no snuffing.

CHEMISTRY OF A LAMP.—A chimney confines the hot air and makes a draught of O through the flame.

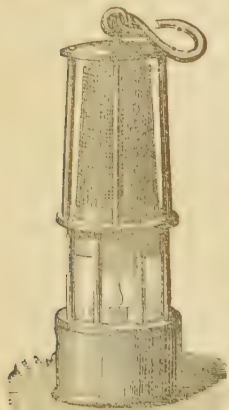


Water in a flame.

A flat wick is used, as it presents more surface to the action of the O. Argand lamps are made with a hollow wick, so as to admit O into the centre of the blaze. The film which gathers on a chimney when we first light a lamp, is the HO produced in the flame, condensed on the cold glass.

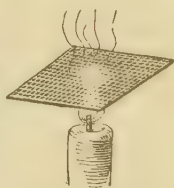
A pint of oil forms a full pint of HO. Spirits of turpentine, tar, pine-wood,

etc., contain an excess of C, and not enough H to heat it to the point of union with O. These, therefore, produce clouds of soot. Alcohol contains an excess of H and little C, hence it gives off great heat and but little light. Davy's Safety Lamp, used by miners, consists of an ordinary oil-lamp, surrounded by a cylinder of fine wire-gauze. Even if the flame of the lamp is thrown against the outside, or inflam-



Davy's Safety Lamp.

mable gases from the mine come into the inside, the wire conducts off the heat, and reduces it below the point of union with O, so no flame can pass through, and no gas on the outside ignite. Through carelessness fearful accidents have occurred, even since this lamp has been used. Miners become extremely negligent, and an account is given of an explosion, in which about a hundred persons were killed, caused by a lamp being hung on a nail by a hole broken through the wire-gauze.



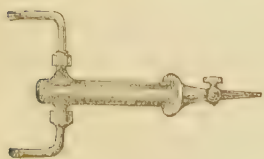
Wire-gauze in flame.

EXTINGUISHING FIRES.—Blowing on a candle or lamp extinguishes it, because it lowers the heat of the flame below the point of union of C with O. Fires are put out by HO partly for the same reason, and also because it envelops the wood and shuts off the air. If a person's clothes take fire, the best possible remedy is to wrap him in a blanket, carpet, coat, or even in his own garments. This smothers the fire, by shutting out the O of the air. Great care should be taken in a fire not to open the doors or windows, so as to cause a draught of air. The entire building may burst into a blaze, when the fire might have been confined for want of O, and so easily extinguished.

SPONTANEOUS COMBUSTION.—Sometimes chemical changes take place in combustible substances, whereby heat enough is generated to cause ignition. Lime occasionally absorbs HO, so as to set fire to

wood in contact with it. Fresh-burned charcoal has the power of absorbing gases in its pores so vigorously as to become ignited. Heaps of coal often take fire from the iron pyrites contained in them being decomposed by the moisture of the air. The waste cotton used in mills for wiping oil from the machinery, is thrown into large heaps, and absorbs O from the air so rapidly that it often bursts into a blaze. Combustion has occurred in heaps of hard-wood ashes which had long lain undisturbed. President Lord, of Dartmouth College, had in his cellar a pile of 25 bushels which became completely ignited. Many similar instances show the danger of keeping even old ashes near combustible substances.

OX-HYDROGEN BLOW-PIPE.* — In the Compound Blow-pipe a jet of O is introduced into the centre of a jet of burning H, producing a *solid flame*.



Inasmuch also as H unites with so much O, an immense heat is developed. A watch-spring will burn in it with a shower of sparks. Platinum, the most infusible of metals,

requiring a temperature of 4591° , or over twenty times that of boiling water, readily melts. In the common hollow flame, as we have seen, the little

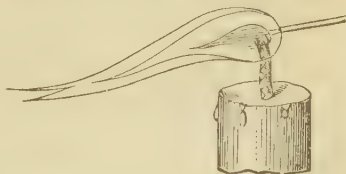
* See Frontispiece.

particles of solid C, heated by the burning H, produce the light. As there is no solid body in the Blow-pipe flame, it is scarcely luminous. If, however, we insert in it a bit of lime, a most dazzling light is produced. This is called the "Drummond," "Lime," or "Calcium" Light, and has been seen at a distance of one hundred and eight miles in broad sunlight.

Blow-pipe.—In the common blow-pipe, used by jewellers, a current of O from the lungs is thrown into the centre of an alcohol blaze. It is thus rendered solid and its heat greatly increased. Near the extreme point of the flame the unconsumed gases are very hot, and combine readily with the O of any substance inserted into the flame at that part, which is therefore called the "*reducing flame.*" Just at the point of the flame, the O thrown from the lungs is highly heated, and is ready to combine with any substance, and is therefore called the "*Oxydizing flame.*" Example: Hold a copper cent in the flame of an alcohol lamp

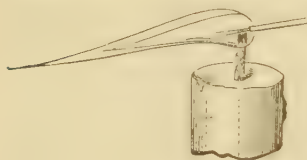


Common Blow-pipe.



Reducing flame.

In the “reducing flame” its rust or oxyd of copper will be all cleaned off, and the cent will shine as brightly



Oxydizing flame.

as if just from the mint.

In the “oxydizing flame” the various oxyds of copper will be formed over the surface, and so the most beautiful play of colors will flash from side to side

as we move the cent from one part to the other.

THE ATMOSPHERE.

The “air we breathe” consists of N, O, CO_2 , and watery vapor. The first composes $\frac{4}{5}$, the second $\frac{1}{5}$, the third $\frac{1}{1000}$, and the last a variable proportion. The N and O form so large a part, that they are considered in ordinary calculation to compose the whole atmosphere. A very clear idea of the proportion of these several constituents may be formed by conceiving the air, not as now dense near the surface of the earth, and gradually becoming rarified as we ascend to its extreme limit of 500 miles, but of a density throughout equal to that which it now possesses near the earth. The atmosphere would then be but about five miles high. The vapor would form a sheet of H₂O over the ground five inches deep, next the CO_2 a layer of 13 feet, then the O a layer of one mile, and last of all, the N a layer of four miles. (*Graham.*) In this arrangement we have supposed the gases to be placed in the order of their specific gravity. The

atmosphere is not thus composed in fact, the various gases being equally mingled throughout, in accordance with a principle called the "*Law of the Diffusion of Gases.*" If we throw a piece of lead into a brook, it will settle instantly to the bottom by the law of gravitation, and remain there forever by the law of inertia. But if we throw out into the atmosphere a quantity of CO_2 , it sinks for an instant, then immediately begins to mingle with the surrounding air, and is soon entirely dissipated. Example: If we invert an open-mouthed bottle full of H over another full of CO_2 , in a few hours the H, light as it is, will have crawled down into the lower jar; and the CO_2 , heavy as it is, will have crawled up into the upper jar; and the gases will be found equally mixed. By this law the proportion of the elements of the atmosphere is the same everywhere, and has not varied within historic times. Samples have been analyzed from every conceivable place, from polar and torrid regions, from prairies and mountain-tops, from balloons and mines, and even from bottles-full sealed up in the ruins of Herculaneum, and the result is the same. These gases do not form a chemical compound, but a mere mechanical mixture, and they are as distinct in the air as so many grains of wheat and corn mingled in a measure. Each of these has its separate use and mission. The action of O and N we have already seen.

Uses of CO_2 .—This bears the same relation to vegetable that O does to animal life. The leaf—the

plant-lungs—through its million of little *stomata*, or mouths, drinks in the CO_2 . In that minute leaf-laboratory, by the action of the sunbeam, the CO_2 is decomposed, the C being applied to build up the plant, and the O returned to the air for our use. Plants breathe out O as we breathe out CO_2 . We furnish vegetables with air for their use, and they in turn supply us. There is thus a mutual dependence between the animal and the vegetable world. Each relies upon the other. Deprived of plants we would soon exhaust the O from the air, supply its place with CO_2 , and die; while they, removed from us, would soon exhaust the CO_2 , and die as certainly. We poison the air while they purify it. Each tiny leaf and spire of grass is thus imbibing our foul breath, and returning it to us pure and fresh.* This interchange of office is so exactly balanced, that, as we have seen, the proportion of CO_2 and of O never varies. “Two hundred million tons of coal are now annually burned, producing six hundred million tons

* In connection with the above subject, it is well to notice that in the darkness some CO_2 does leak out, as it were, from the leaves of plants; while flowers exhale CO_2 in large quantities, as has been recently shown. On this account the presence of flowering plants, especially, must be injurious in a close room. In this respect chemistry sadly interferes with the beautiful custom of adorning our apartments in this simple manner. If we retain the plants, we must ventilate more thoroughly on that account.

of CO_2 . A century ago, hardly a fraction of that amount was burned, yet this enormous aggregate has not changed the proportion in the least." (*Youmans.*)

Use of Watery Vapor.—We have already seen the uses of HO. As vapor, it is everywhere present and ready to supply the wants of animals and plants. Were the air dry, our flesh would shrivel into that of a mummy, and leaves would wither as they do in an African simoom. Rivers and streams flow to the ocean; yet all their fountains are fed by the currents that move in the air above us. HO rises in the air as vapor, flows on to colder regions, falls as rain, dew, snow, or hail, and then working as it goes whatever it finds to do, moistening a plant or turning a water-wheel, it wends its way back to the ocean. Thus Niagara itself must first have risen to the clouds as vapor before it could fall as a cataract.

PERMANENCE OF THE ATMOSPHERE.—Did the elements readily unite to form nitric acid, instead of, as now, with great difficulty, and only in a thunder-storm, we would be constantly exposed to a shower of this corrosive acid that would be destructive to all vegetation, clothing, and even our bodies themselves.—O and N have never been solidified or liquefied by the severest cold or pressure, while CO_2 requires a force that is never reached in nature. Watery vapor, on the contrary, is deposited as dew or rain by a slight change of temperature; this is necessary to supply the wants of vegetation and life. But were the same true of the other constituents,

they would come raining down upon us in most disastrous showers; and in winter we should be compelled to melt what air we should need, and carry a supply with us constantly. Life itself would be unendurable under such circumstances. Again, the permanence of the air produces all the uniformity of sound. Were the proportions of the atmosphere to change, all "familiar voices" would become strange and uncouth to us, while the harmonies of music would shock us with unwonted discord. If, by some means, the air of a concert-room could be changed to H, for instance, the bass voices would become irresistibly comic and shrill, while the tenor would emulate railway whistles. It is pleasant to notice how each element of the air is adapted for a special work, and all fitted to the present order of nature.

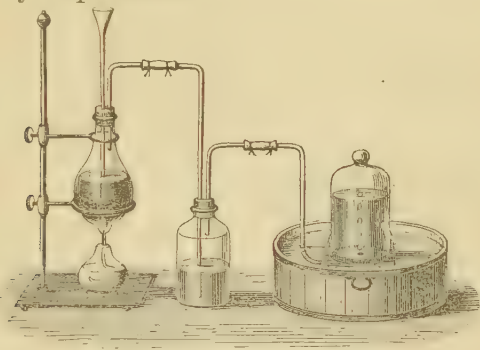
THE HALOIDS.

Chlorine	Symb., Cl;	Equiv., 35.5;	Spec. Grav., 2.47
Iodine	" I;	" 126.8;	" 2.47
Bromine....	" Br;	" 80.;	" (at 30°), 3.18
Fluorine....	" F;	" 19.;	" 1.31

These four elements are closely allied, and form a class of compounds known as the *haloid salts*, from *hals*, salt, because they resemble common salt.

CHLORINE is named from its green color. It is chiefly found in common salt, of which it forms 60 per cent., and is made by moderately heating it with black oxyd of manganese, sulphuric acid, and water. This mixture liberates the gas in great quantities.

It is heavier than common air, and so may be collected by displacement.



Making Chlorine.

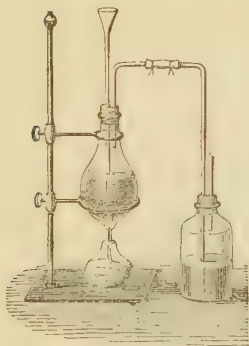
Properties.—It has a greenish-yellow color, and a peculiarly disagreeable odor. It produces a suffocating cough, which can be relieved by breathing ammonia or ether. Arsenic, antimony, Dutch gold-leaf, phosphorus, etc., combine with it so rapidly as to inflame;—powdered antimony producing a shower of brilliant sparks when slowly dropped into a jar of Cl. Cold water absorbs about twice its volume of the gas, which soon turns to hydrochloric acid (HCl) in the sunlight. It has such a powerful affinity for H, that it will even attract it out of a moist organic body, and form HCl. It acts thus upon turpentine, depositing its C in great flakes of soot. It discharges the color of indigo, ink, wine, etc., almost instantaneously. It has no effect on printers' ink, as that contains no H.



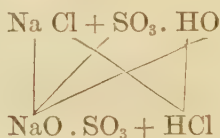
Turpentine
in Cl.

HYDROCHLORIC ACID (HCl)—*Muriatic Acid*.—When

Cl and H are mixed and exposed to the direct sunlight they unite with an explosion. In the arts, HCl is prepared from sulphuric acid and common salt.



Making HCl.



Properties.—It is an irrespirable, irritating, acid gas, with an intense attraction for HO, which causes it to produce white fumes in the air. Water absorbs 480 times its bulk, forming the liquid known as “*Muriatic Acid*.” It unites with the metals, and forms chlorides. When pure it is colorless, but has ordinarily a yellow tinge, due to various impurities. Its tests are ammonia, with which it forms a white cloud of sal-ammoniac fumes, and nitrate of silver, from which it precipitates chloride of silver. With NO₅ it forms aqua-regia, or *royal water*, so named because it dissolves gold, the “king of the metals;” it sets free chlorine, which, in its nascent state, attacks the gold and combines with it.

CHLORIDE OF LIME (*Bleaching Powder*).—This is prepared by passing a current of Cl over pans of

fresh slacked lime. It is much used in bleaching and as a disinfectant.

Bleaching.—In domestic bleaching the cloth is first boiled with strong soap, to dissolve all the grease and wax, and then laid upon the grass, being frequently wet to hasten the action of the air and sun. The dew seems to have a peculiar influence, while the corrosive ozone of the atmosphere doubtless aids in the process. The H of the coloring matter unites with the O of the air or dew, forming HO, and thus destroying the coloring compound. This was essentially the process long pursued in Holland, where all linens were formerly carried for bleaching: hence the term “Holland linen,” still in use. The HO about Haarlem was thought to have peculiar properties, and no other could compete with it. Cloths sent there were kept the entire summer, and were returned in the fall. Later a similar plan was adopted in England. But the vast extent of grass-land required, the time occupied, and the temptation to theft, made the process extremely tedious and expensive. The statute laws of that time abound in penalties for cloth stealing. It is estimated that all the men, women, and children in the world could not, by the old way, bleach all the cloth that is now used. At present the cloth is well washed, and boiled in water with strong alkalies, to remove the grease, &c.; next it is passed through a solution of chloride of lime, and lastly through diluted SO_3 . In this step the SO_3 unites with the lime, and sets free

the Cl, which in turn combines with the H of the coloring matter, forming HCl, and thus bleaches the cloth most perfectly. About twenty-four hours are required for this process, and the cost is not quite a cent per yard. Paper rags are bleached in the same way in paper-mills. Stains can be removed from *uncolored cloth* by a little chloride of soda (Labarraque's Solution), which can be obtained of any druggist. Place the cloth in this liquid, and if obstinate, pour on a little boiling HO, or place it in the sun for some hours. Then rinse thoroughly in cold HO, and dry.

Disinfectant.—Chlorine is a powerful disinfectant. It breaks up the offensive substance by uniting with its H, as in bleaching. Other disinfectants, as burnt paper, sugar, etc., only disguise the ill odor by substituting a stronger one. In the sick-room Cl is set free from chloride of lime by exposing it to the air in a saucer with a little HO. The gas soon passes off, though the process may be hastened by adding a few drops of dilute SO_3 . Chloride of lime (Bleaching powder) is, therefore, of great service for disinfecting all places exposed to any noxious or unpleasant effluvia.

BROMINE—named from its bad odor—is a poisonous, volatile, deep-red liquid, with the general properties of Cl. It is principally found in sea-water, and forms bromides with the metals, which are used in photography.

FLUORINE is the only element that will not unite

with O. It exists, in small quantities, in the enamel of the teeth. It is found in Derbyshire or fluor spar (Ca.Fl), of which beautiful ornaments are made. It unites with H, forming hydrofluoric acid (HFl), noted for its corrosive action on glass. This eats out the silica or sand from the glass, and is therefore used for etching labels on glass bottles and names on shop-windows. Example: Powdered fluor spar is placed in a lead tray, and covered with dilute SO_3 . The heat of a lamp applied beneath, for a moment only, liberates the gas in white fumes very rapidly. The plate of glass is covered with wax, and the design to be etched is traced upon it with a sharp-pointed instrument. This is then laid over the tray, and the escaping gas soon etches the lines laid bare into an appearance like ground glass. A solution of HFl in HO is often sold for this purpose. It is kept in lead or gutta-percha bottles, combines with HO with a hissing sound, like red-hot iron, and must be handled with care, as a minute drop even will sometimes produce an incurable ulcer.

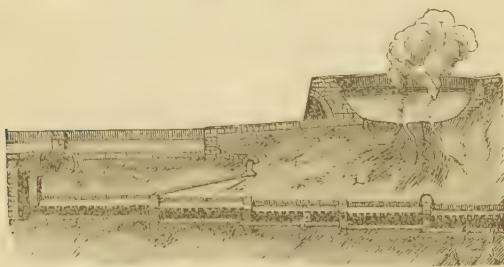
IODINE is named from its beautiful violet-colored vapor. It is made from kelp—the ashes of sea-weed, and is found in sea-water and in some mineral springs. It has a bluish-black, metallic appearance, and is sparingly soluble in HO , but readily in ether or alcohol. It inflames spontaneously when in contact with phosphorus. Its compounds with the metals, called the iodides, are remarkable for their variety and bril-

liancy of color. It stains cloth a yellowish tint, which may be removed by a solution of iodide of potassium. Its test is starch, forming the blue iodide of starch. It reveals the presence of this substance in potatoes, apples, etc. It is much used in medicine to scatter scrofulous or cutaneous eruptions and swellings.

BORON.

Symbol, B Equivalent, 10.9.

BORON is known in nature only in combination with O, as boracic acid (BO_3). This is found in the volcanic districts of Tuscany. Here, for an area of about 30 miles, is a wild, mountainous region, of terrible violence and confusion. The surface is ragged and blasted. Everywhere there issue from the ground jets of steam, filling the air with most offensive odors. The earth itself shakes beneath the feet, and frequently yields to the tread, engulfing man and



Preparing BO_3 .

beast. "The waters below are heard boiling with strange noises, and are seen breaking out upon the

surface. Of old, it was regarded as the entrance to hell. The peasants pass by in terror, counting their beads and imploring the protection of the Virgin." In the midst of this scene of horror a most lucrative business has been established. These jets of steam are charged with boracic acid. A series of basins are excavated up the sides of the principal mountain. These are filled with cold HO from the neighboring springs. Into these basins the jets of steam are conducted. The HO absorbs the boracic acid, and becomes itself heated to the boiling-point. It is then drawn off into the next lower basin. This process is continued until the bottom one is reached, when the HO runs into leaden pans heated by the steam from the earth; here the HO is evaporated, and the boracic acid is collected. 3,000,000 lbs. are sold per annum.

BORAX is a biborate of soda ($\text{NaO} \cdot 2\text{BO}_3$). It is employed largely in welding. It dissolves the oxyd of the metal, and keeps the surface bright for soldering. It softens hard water by uniting with the soluble salts of lime or magnesia, and making insoluble ones which settle and form a thin sediment in the bottom of pitchers in which it is placed.

SILICON.

Symbol, Si Equivalent, 14.

Sources.—This is commonly found in combination with O, as silicic acid, silica, silex or quartz (SiO_2). This oxyd composes 45 per cent. of the earth's crust.

It forms beautiful crystals and some of the most precious gems. When pure, it is transparent and colorless, as in rock-crystal. Jasper, amethyst, agate, chalcedony, opal, topaz, chrysoprase, sardonyx, etc., are all common flint-stone or quartz, colored with some metallic oxyd. Sand is mainly fine quartz, which, when hardened and cemented, we call sand-stone. Yellow or red sand is colored by iron-rust.

Properties.—It is tasteless, odorless, and colorless. It seems very strange to call such an inert substance an acid; yet it is a *true acid*, since it unites with the alkalis, neutralizes their properties, and forms a large class of salts known as the silicates, which are found in the most common rocks—Example: granite.

SILICA IN SOIL AND PLANTS.—Silica is insoluble in HO, unless it contains some alkali. When the silicates, so abundant in rocks, disintegrate and form soil, the alkali and silica are both dissolved in the water, and taken up by the roots of plants. We see the silica as grit in maple-sugar, or as deposited on the surface of scouring-rushes or sword-grass, on which we have so often cut our fingers. It gives stiffness to the stalks of wheat and other grains, and produces the hard, shiny surface of bamboo, corn, etc.

PETRIFICATION.—Certain springs contain large quantities of some alkali; their waters, therefore, dissolve silica abundantly. If we place a bit of wood in them, as fast as it decays, particles of silica will take its place—atom by atom—and thus petrify the

wood. The wood has not been *changed to* stone, but has been *replaced by* stone.

SULPHUR.

Symbol, S Equivalent, 16 Specific Gravity, 2.

Sources.—Sulphur is found native in volcanic regions. It is mined at Mount *Ætna* in great quantities. Combined with the metals it forms sulphurets, known as cinnabar, iron pyrites, etc. Combined with O it exists in gypsum (plaster), heavy spar, and other sulphates. It is found in the hair, and many dyes contain lead which unites with this S, and forms a black compound that stains the hair. It is contained in eggs, and so tarnishes our spoons by forming a sulphuret of silver. It is always present in the flesh, and hence manifests itself in our perspiration; with some persons it is so abundant as to produce a disagreeable odor. In commerce it is sold as brimstone, formed by melting S and running it into moulds; also as flowers of sulphur, obtained by *sublimation*.

Properties.—It is insoluble in HO, and hence tasteless, although when taken in molasses it seems otherwise. Its solvent is bisulphide of carbon, but it will dissolve somewhat in oil of turpentine. It is a non-conductor of heat, and crackles when we grasp it with a warm hand. It manifests itself under three allotropic forms: 1st, octahedral crystals; 2d, prismatic crystals; 3d, an amorphous (without form) or uncrystallized state. The last is the most interesting. Example: If sulphur be melted, and

then heated up to 480° , it changes into a thick, viscid, dark-colored liquid like molasses, which, if poured into cold water, is elastic like india-rubber. In this form it is used for taking impressions of medals, coins, &c.

SULPHUROUS ACID (SO_2), an irrespirable, suffocating gas, is formed by S burning in the air, as in the lighting of a match. It is very poisonous, and extinguishes combustion. If our "chimney burns" at any time, we can easily quench the flame by pouring a little S into the stove. Its compounds are called sulphites.

Uses.—It is used for bleaching silk, straw, and woollen fabrics. Cl cannot be used for these substances, as it turns them yellow, but SO_2 unites with the coloring matter, and forms a colorless compound. Its action is therefore very different from that of Cl. Example: A red rose, bleached in the fumes of burning S, can be restored to its original color by a little very dilute SO_3 . This acid being stronger, neutralizes the action of the SO_2 . New flannels, washed in strong soap, turn yellow, because the alkali of the soap unites with the SO_2 used in bleaching the cloth, and thus sets free the original color.

SULPHURIC ACID (SO_3)—*Oil of Vitriol, the "King of the Acids."*—This acid is of the utmost importance to the manufacturer and chemist, as it is used in the preparation of nearly all other kinds, forming many valuable compounds. The acid of the shops

is a strong solution of SO_3 in HO . Its compounds are called sulphates.

Preparation.—Example: If in a jar we burn a little S, it will soon become filled with the fumes of SO_2 . One atom of O added to this SO_2 would make it SO_3 . It will be remembered that NO_5 easily parts with its O. Now if we stir the fumes with a swab wet with NO_5 , we shall notice that the white gas in the jar turns red, and shall recognize the old “nitrous acid fumes,” and on testing we shall find SO_3 in the jar, especially if there be any HO at the bottom to absorb it. The nitric acid has turned the SO_2 into SO_3 . This is essentially the plan pursued in its manufacture on a large scale. An immense chamber, perhaps three hundred feet in length, is lined with lead and intersected by perforated leaden partitions to mix the gases more thoroughly as they pass through. In this are



Making SO_2 and SO_3 .



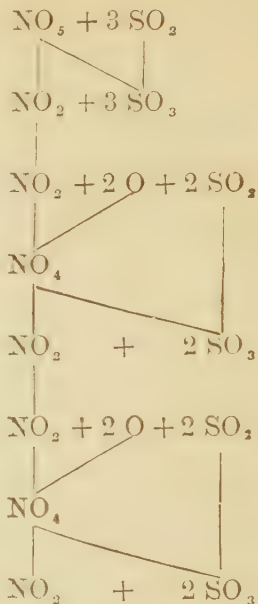
Manufacture of SO_3 .

admitted *steam*, fumes of *burning sulphur*, and *nitric acid*, from furnaces at the side.

The NO_5 gives 3 atoms of O to the SO_2 , making 3 molecules of SO_3 , reducing itself to NO_2 . Not content with the work now done, in its anxiety to supply the wants of the SO_2 , the NO_2 takes up 2 O from the air

in the room, becoming NO_5 , and flies back to the SO_2 , making 2 molecules more of SO_3 . Reduced to NO_2 again, it once more seeks the air and returns laden with O for the SO_2 . A small quantity of NO_5 , introduced in the beginning, will make an almost unlimited amount of SO_3 . The steam hastens the chemical operation by its warmth and moisture. There is a thin layer of HO on the floor. This absorbs the SO_3 , and is gradually drawn off and condensed by evaporation in lead pans, and finally, when the SO_3 begins to corrode the lead, in large platinum vessels. It is lastly put in large bottles packed in boxes called *carboys*, when it is ready for transportation.

Properties.—It is a dense oily liquid, without odor, and of a brownish color. It freezes at -30° and boils at 610° . It is a hydrate, containing a molecule of HO to one of SO_3 , thus $\text{SO}_3 \cdot \text{HO}$. Its affinity for moisture is most remarkable. If exposed in an open bottle it gradually absorbs the water of the air, and increases in bulk. It will in time double its weight in this way. It blackens wood and other organic



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substances, by taking away their HO and leaving the C. When SO_3 is mixed with HO, it occupies less space than before, and liberates much heat, 4 parts of acid to 1 of HO will boil a test-tube of HO. It commonly contains lead, which falls as a milky precipitate when the acid is mixed with HO. It is the strongest of the acids, and will displace the others from their compounds. It stains cloth red, but the color can be restored with any alkali ;—NaO. CO_2 is best. Its test is chloride of barium, which forms a beautiful white cloudy precipitate. In this way a drop of SO_3 in a quart of HO can be distinctly detected. Experiment : Strong oil of vitriol poured on a little loaf-sugar moistened with hot water, will cause an energetic boiling and a copious formation of black charcoal. Sugar consists of water and charcoal, and gives up all the former to satisfy the appetite of the SO_3 .

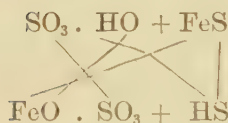
NORDHAUSEN ACID is the ancient *oil of vitriol* made in Germany from green vitriol. It is the strongest sulphuric acid known, and may be separated from its HO by distillation, when the acid will appear as white silky flakes, which may be handled with impunity, and will hiss when thrown into HO.

SULPHIDE OF HYDROGEN (HS)—*Sulphuretted Hydrogen*.—This gas is produced in the decay of organic matter, and is always found near cesspools, drains, and sinks, turning the paint black and emitting a disagreeable smell. It gives the characteristic odor to the mineral waters of Avon, Clifton, Sharon, and

Saratoga. It is prepared by the action of dilute SO_3 upon sulphuret of iron.



Making HS.



It has the disgusting odor of rotten eggs, is very poisonous, and, therefore, makes an open sewer very destructive to health. Its solution in HO is much used in the laboratory to precipitate the metals as a sulphuret. Its test is acetate of lead (sugar of lead.)

BISULPHIDE OF CARBON (CS_2) is produced by passing the vapor of S over red-hot coals. It is a volatile, colorless liquid, and has never been frozen. It is strange that a yellow odorless solid should unite with a black odorless solid to form such a colorless odoriferous liquid; it thus illustrates very finely the

power of chemical affinity. It readily dissolves sulphur, phosphorus, and iodine. It is a powerful refractor of light, and is used for filling hollow glass prisms—the most perfect known—for experiments with the solar spectrum.

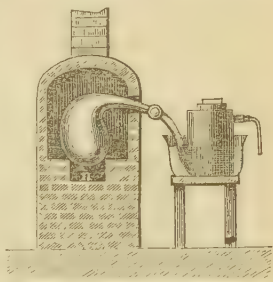
PHOSPHORUS.

Symbol, P Equivalent, 31 Specific Gravity, 1.83.

Its name signifies *light-bearer*, given because of its glowing in the dark. It was called by the old alchemists, “the son of Satan.”

Sources.—It exists in small quantities in rocks, and by their decay passes into the soil, is taken up by plants, is then stored in their seeds (wheat, corn, oats, etc.), and finally passes into our system. As a phosphate of lime, it is the principal constituent of our bones. Phosphorus is so necessary to the operation of the brain that the alchemists had a saying, “No phosphorus, no brains.”

Preparation.—It is prepared in immense quantities from bones. These are first calcined to whiteness to burn out the animal matter, then treated with SO_3 to remove the lime, and lastly heated to a high temperature with C to deoxygenize them, when the P distils as a vapor, which is condensed under HO.



Manufacture of Phosphorus.

Properties.—It is a waxy, transparent solid, at all temperatures above 32° emits a feeble light, melts at 111° and ignites at a temperature a little above this. It should be handled with the utmost care, always kept and cut under HO , and never used except in very small quantities. Its burns are deep and dangerous. It is very poisonous, and is the basis of all rat-exterminators. Its vapor produces horrible ulcerations of the jaw-bone in workmen who use it. In burning, it unites with five atoms of O , forming phosphoric acid (PO_5), whose compounds are called phosphates.

Amorphous Form.—Heated for 48 hours at a temperature of 480° , in a close vessel, P is changed into a brick-red powder, and seems to have lost all its former properties. It can be handled with impunity, and carried in the pocket like so much snuff. By heating it again to a higher point, it goes back to its old form.

Uses.—MATCHES.—The principal use of P is in the making of matches. The match is first dipped in melted sulphur and dried, then in a paste of P , nitre and glue, which completes the process. The object of the nitre is to furnish O to quicken the combustion. Instead of this, chlorate of potash is sometimes used, and can be recognized by the crackling sound and jets of flame when ignited. The tips are colored by red-lead, or Prussian blue, mixed in the paste. When a match is burned, the reaction is as follows: first, the friction ignites the P , which burns, forming

PO_5 ; this produces heat enough to inflame the S, which makes SO_2 ; lastly, the wood takes fire, and forms CO_2 and HO . Thus there are four compounds produced in the ignition of a single match. The phosphorus produces an intense heat, but will not ignite the wood, since, in burning, it produces an ash (PO_5) which covers the wood as with a varnish.

PHOSPHORESCENCE.—The luminous appearance of putrefying fish and decayed wood is well known. The latter is sometimes called “fox-fire.” The “glow-worm’s fitful light” is associated with our memory of beautiful summer evenings. In the West Indies, fire-flies are found that emit a green light when resting, and a red one when flying. These are so brilliant that one will furnish light enough for reading. The natives wear them for ornaments on their bou-nets, and illuminate their houses by suspending them as lamps.—The ocean, at times, takes on strange colors, and the sailor finds his vessel plowing at one time apparently a furrow of fire, and at another one of liquid gold. The water is all aglow, and the flames seem to leap and dance with the waves or the motion of the ship. These phenomena are produced by multitudes of animalculæ which frequent certain seas. Phosphorescence is generally attributed to the gradual oxydation of the phosphorus secreted by the animal or plant, or to electrical action.

PHOSPHURETTED HYDROGEN (PH_3) is formed in the decomposition of bones and organic substances. With HS it gives rise to the odor of slaughter-houses. It

is a poisonous gas, remarkable only for its disgusting odor and the singular beauty of the rings formed by its smoke ascending through the air. It is prepared by dropping bits of phosphuret of calcium into HO. It has been thought by some that the Will-o'-wisp, Jack-o'-the-lantern, etc., as seen near graveyards and in swampy places, is produced by this gas coming off from decaying substances, and igniting as it reaches the air. (See app. p. 243).

THE METALS.

THE METALS OF THE ALKALIES.

These are *potassium*, *sodium*, *lithium*, and *ammonium*. The last two are of no general interest.

POTASSIUM.

Symbol, K Equivalent, 39 ... Specific Gravity, 0.85.

Source. This metal was discovered by Sir Humphrey Davy, in 1807, by the decomposing action of a powerful galvanic battery. By passing the current through potassa (KO), the K went to the negative pole, and the O to the positive. In the same manner he separated the metals sodium, barium, strontium, and calcium. This discovery constituted a most important epoch in chemistry. K is found abundantly in nature in the various rocks which, by their decom-

position, furnish it to the plants, from whence we obtain our entire supply.

Properties.—It is a silvery-white metal, soft like wax, and light enough to float like cork. Its affinity for O is so great, that it is always kept under the surface of naphtha, which contains no O. K, when thrown on HO, decomposes it, unites with its O, forming KO, and sets free the H. The heat developed is so great, that the H catches fire and burns with some volatilized K, which tinges the flame with a beautiful purple tint. If the HO be first colored with red litmus, it will become blue by the alkali (KO) formed.



Potassium on water.

POTASSA (KO)—*Potash*.—This is a grayish-white solid, made from $\text{KO} \cdot \text{CO}_2$ by the action of lime. It is the most powerful alkali. It neutralizes the acids, and turns red litmus to blue. It is used to cauterize the flesh, and is hence commonly called “caustic potash.” It dissolves the cuticle of the finger which touches it, and so has an unctuous feel, as we see in strong soap. It unites with grease, forming soap, and is extensively used for that purpose. Its affinity for HO is so great, that it is usually known only as a hydrate ($\text{KO} \cdot \text{HO}$). It also absorbs CO_2 from the air, and must be kept in close-stoppered bottles. It is a corrosive, deadly poison. Its test is bichloride of platinum, forming a yellow precipitate from a solution.

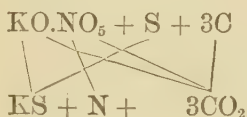
CARBONATE OF POTASH ($\text{KO} \cdot \text{CO}_2$)—*Pearlash*.—Pot-

ash is contained in plants, combined with various acids, such as tartaric, malic, oxalic, etc. When the wood is burned, the CO_2 of the fire drives off these acids, and combines with the KO , forming KO.CO_2 . The ashes are then leached, and the *lye* which is formed is evaporated until the KO.CO_2 crystallizes. Birch gives the purest potash, while the leaves furnish 25 times as much as the heart of a tree. Where wood is abundant, immense quantities are burned solely for the ashes. *Saleratus* is a bicarbonate of potash (KO.2CO_2), and is formed by passing a current of CO_2 through the carbonate.

NITRATE OF POTASH (KO.NO_3)—*Saltpetre*: *Nitre*.—This salt is found abundantly in Egypt and the East Indies, mixed with the soil. It is obtained thence by leaching. It is formed artificially by piling up great heaps of mortar, refuse of sinks, stables, etc. In about three years these are washed, and each cubic foot of the mixture will furnish four or five ounces of saltpetre. It was manufactured in the Mammoth Cave, Kentucky, during the war of 1812. It dissolves in one-third of its weight of hot water.

Properties and Uses.—It is cooling and an antiseptic: hence it is used for salting meat, to which it gives a reddish tint. It parts with its O readily and burns brilliantly. Every government keeps a large supply on hand for making gunpowder, in the event of war. Gunpowder is composed of three parts charcoal, and one each of saltpetre and sulphur. Its explosive force is due to the expansive power of the

gases formed. The combustion is started by the saltpetre giving up all its O to burn the S and C. The reaction that ensues may be *very simply* stated as follows :



N and CO₂ are gases, and in that great heat of nearly 2,000°, high enough to melt gold or copper, the KS becomes a vapor. With the sudden increase of temperature, they expand till they occupy 2,000 times the space of the powder. The bad odor of burnt powder is due to the slow formation of HS in the residuum. Fireworks are composed of gunpowder ground with additional C and S, and some coloring matter. Zinc filings produce green stars, steel filings variegated ones. A little chlorate of potassa tinges the flame with crimson. Salts of copper give a blue or a green light, and camphor a pure white one.

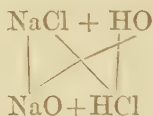
SODIUM.

Symbol, Na Equivalent, 23 Specific Gravity, 0.972.

This metal is found principally in common salt. It is very like K in its appearance, properties, and reaction. When thrown on HO it rolls over its surface like a beautiful little silver ball : if the HO be heated, it bursts into a yellowish blaze. The test of

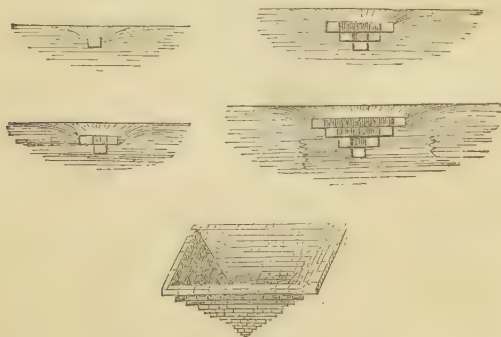
all the soda salts is the yellow tint which their solution in alcohol gives to the flame.

CHLORIDE OF SODIUM (NaCl), *common salt*, is the only mineral substance which is absolutely necessary to the life alike of all human beings and the higher order of animals. Among the many cruel punishments inflicted in China, deprivation of salt is said to be one, causing at first a most indescribable longing and anxiety, and finally a painful death. Dr. Draper tells us that the salt and the HO in the stomach undergo the following reaction (see app.):



Both these are essential in forming gastric juice and bile, and to make enough of them to keep up the proper digestion of our food, requires about one-third of an ounce of NaCl . As salt is so universally necessary, it is found everywhere. Our Father, in fitting up a home for us, did not forget to provide for all our wants. The quantity of salt in the ocean is said to be equal to five times the mass of the Alps. Salt lakes are scattered here and there; saline springs abound; and besides these, in the earth are stored great mines, probably produced by the evaporation of salt lakes in some ancient period of the earth's history. At Cracow, Poland, is a bed twelve hundred miles long, twenty miles wide, and a quarter

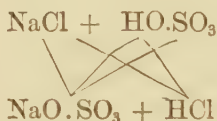
of a mile thick. In Spain, and lately in Idaho, it has been quarried out in perfect cubes, transparent as glass, so that a person can read through a large mass. On the sea-shore it is manufactured by the evaporation of sea-water, each gallon containing about four ounces. At Syracuse, New York, near by and underneath the Onondaga Lake, is apparently a great basin of salt-water, separated from the fresh-water above by an impervious bed of clay. Penetrating this to a depth of about seven hundred feet, the saline water is pumped up in immense quantities. The State sells this to salt manufacturers, on the payment of a cent per bushel on the salt made. The HO is evaporated by heating in large iron kettles or vats, or in the sun, whence the name "solar salt." If boiled down rapidly, fine table-salt is made; if more slowly, coarse salt, as large crystals have time to form. Frequently they assume a "hopper shape"—one cube appears, then others



Hopper Form.

collect at its edges, and gradually settle, until a hollow pyramid of salt-cubes, with its apex downward, is formed. About seven million barrels are made annually at this city. Salt dissolves equally well in hot or in cold water, and a *saturated* solution (one containing all it will dissolve) has 37 per cent. of salt.

SULPHATE OF SODA ($\text{NaO}.\text{SO}_3$), *Glauber's salt*, named from the discoverer, is made from common salt.



Experiment: Make a saturated solution of sulphate of soda, and with it fill a bottle. Either put in the glass stopple or cover the top with a thin layer of oil, and let the bottle stand. The salt will remain for weeks or even months without crystallizing; but if it be taken up, and shaken ever so little, the whole mass will instantly form into crystals, so filling the bottle that not a drop of water will escape, even if it be inverted. Should there be any hesitation in crystallizing at the moment, drop into the bottle a minute crystal of Glauber's Salt, and the effect will instantly be seen in the darting of new crystals in every direction.

CARBONATE OF SODA ($\text{NaO}.\text{CO}_2$), *sal-soda*, is used in immense quantities in the manufacture of glass,

soap, etc. (See Appendix, Problem 40.) It is employed, like borax, to soften hard water, by combining with the lime and magnesia, and making insoluble carbonates, which settle to the bottom. In washing, it unites with the grease in the clothes, and forms soap.

BICARBONATE OF SODA ($\text{NaO} \cdot 2\text{CO}_2$) is the “soda” of the cook-room, and is formed, like saleratus, from its carbonate.

SILICATE OF SODA AND LIME ($\text{NaO} \cdot \text{SiO}_2 + \text{CaO} \cdot \text{SiO}_2$)—*French plate and window glass.* Glass was known to the ancients. Hieroglyphics, that are as old as the sojourn of the Israelites in Egypt, represent glass-blowers at work, much after the fashion of the present. In the ruins of Nineveh, articles of glass, such as vases, lenses, etc., have been discovered. Mummies, three thousand years old, are adorned with glass beads. The inventor is not known. Pliny tells us that some merchants, once encamping on the sea-shore, found in the remains of their fire bits of glass, formed from the sand and ashes of the sea-weed by the heat; but this is impossible, as an open fire could not be sufficient to melt these materials. In the fourth century, the glass-works at Alexandria produced most exquisite ornaments, with raised figures beautifully cut and gilded. As late, however, as the twelfth century, a house with glass windows was esteemed something magnificent; and we read that in 1577, during Queen Elizabeth’s reign, when the

Duke of Northumberland came to town to pass the winter, the windows of his castle were taken out and packed away for safe-keeping until spring.

Preparation.—Glass is a double silicate, being composed of silica and any two of the alkaline bases, lime, soda, potash, or magnesia. Example: Fine white sand is mixed with sal-soda and lime, and then heated in earthen pots to the most intense degree for forty-eight hours. The materials fuse and form a double silicate of soda and lime. This is common window-glass. A variation in the materials used produces different kinds of glass. The only essential ingredients are sand and soda or sand and potassa. Lime hardens and gives lustre, while soda imparts a green tint. Arsenic whitens it. Oxyd of lead is used in large quantities, as high as one-half the weight, to form a soft glass, which can be ground into imitation gems, table-ware, chandelier pendants, prisms, etc. Oxyd of iron gives an opaque green, as in common junk or green glass bottles. Boracic acid increases the refractive power for lenses in microscopes and telescopes.

Bohemian glass is a silicate of potash and lime, and thus does not show the green tint of soda. Pulverized flint was formerly used for sand, and hence the term *flint-glass*.

COLORING GLASS.—A small quantity of some metallic oxyd, melted with the glass, gives any tint desired: AuO gives a ruby red; MnO, an amethyst; CuO, an azure blue; As and Sb a soft white enamel, as in

lamp-shades; SnO_2 , a hard enamel, as in watch-faces.

ANNEALING GLASS.—If the glass utensils were immediately used, they would be found extremely brittle, and would drop in pieces in the most unaccountable way. The heat of the hand or a draft of cool air would sometimes crack off the thick bottom of a tumbler. They are therefore cooled very gradually for days, which allows the particles to assume their natural place, and the chemical attractions to become equalized. This principle is beautifully illustrated by the chemical toy known as the "Prince Rupert's Drop."

ORNAMENTAL WARE.—Venetian balls or paper weights are made by arranging bits of colored glass in the form of fruits, flowers, etc., and then, inserting this ball into a hollow globe of transparent glass, still hot, the workman draws in his breath, and the pressure of the air above collapses the globe upon the colored glass, and leaves a concave surface in the top of the weight. The lens form always magnifies the size of the figures within.

TUBES AND BEADS.—In making glass tubing, the workman inserts his iron blowing-tube into a pot of melted glass, and gathers upon the end a suitable amount: drawing this out, he blows into the tube, swelling the glass into a globular form. Another dip into the pot and another blow increase its size, until at last a second workman attaches an iron rod to the other end. The two men then separate on a

rapid trot. The soft glass globe diminishes in size as it lengthens, until at last it hangs between them a glass tube of one hundred feet in length, and perhaps only a quarter of an inch in diameter. In making beads, these glass tubes are cut in small bits, and then worked about in a mixture of wet ashes and sand, until they are filled. Next they are put with loose sand into a rapidly-revolving cylinder over a hot furnace. The heat softens the glass, but the mixture within presses out the sides, and the sand grinds the edges, until at last the beads become round and perfect, and are taken out ready for market.

AMMONIUM.

AMMONIUM (NH_4) has never been separated, but is thought to be the base of ammonia (NH_3). In combination NH_3 combines with a molecule of HO , becoming $\text{NH}_3.\text{HO}=\text{NH}_4.\text{O}$. This is considered as the oxyd of the compound radical ammonium. Example: $\text{NO}_5+\text{HO}+\text{NH}_3$ uniting, form $\text{NH}_3.\text{HO}.$ $\text{NO}_5=\text{NH}_4.\text{O}.\text{NO}_5$.

METALS OF THE ALKALINE EARTHS.

These are Ba, Sr, Ca, and Mg, but the last two only are of general interest.

CALCIUM.

Symbol, Ca....Equivalent, 20....Specific Gravity, 1.57.

This metal exists abundantly in limestone, gypsum, and, combined with phosphoric acid, in the bones of the body. It is commonly known only as an oxyd.

CaO (CAUSTIC or QUICKLIME) is obtained by heating limestone ($\text{CaO} \cdot \text{CO}_2$) in large kilns. The CO_2 is driven off by the heat, and leaves the lime as a white solid.

Properties.—It is a strong alkali, and corrodes the flesh. Its test is CO_2 , producing a milky precipitate of $\text{CaO} \cdot \text{CO}_2$. It has such a strong affinity for HO, that 28 lbs. of lime will absorb 9 lbs. of HO, forming $\text{CaO} \cdot \text{HO}$, or “slacked lime,” and swelling up to three times its original size, with the evolution of much heat. CaO absorbs HO from the air, and then CO_2 , thus gradually becoming a carbonate of lime—“air-slacked lime.” It is more soluble in cold than hot water. A thin film of carbonate of lime will soon gather over a solution of lime exposed to the air.

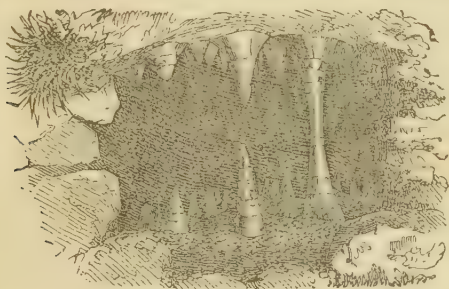
Uses.—It is used in tanning leather to remove the hair. Whitewash is a “milk of lime”—i. e., a mixture of CaO and HO. In mortar, lime hardens rapidly,

in part by uniting with the silica of the sand to form a silicate, and also by absorbing CO_2 from the air to form carbonate of lime. In this process, the HO which the lime absorbed in slacking is given off; this causes the dampness always seen on newly-plastered walls when the room is first warmed. For drying plastering it would be much better if the CO_2 of the fire could be sent directly into the room, as it would hasten the chemical change. "If common mortar be protected from the air it will remain without hardening for many years. It is stated that lime still in the condition of a hydrate has been found in the pyramids of Egypt. When the ruins of the old castle of Landsberg were removed, a lime-pit, that must have been in existence 300 years, was found in one of the vaults. The surface was carbonated to the depth of a few inches, but the lime below this was fresh as if just slacked, and was used in laying the foundations of the new building." (*Am. Cyc.*)

If the lime contains a little clay, it is called *water-lime*, and will harden under water. Lime is valuable as a fertilizer. It acts by rapidly decomposing all vegetable matter, and thus forming ammonia for the use of plants. It also sets free the alkalies that are combined with silica in the soil, and furnishes them to the plants. It does not itself feed the plants, as almost any soil contains enough lime for that purpose. If applied to a compost heap, it will set free ammonia, which can be recognized by the odor: this is its most valuable constituent. The NH_3 can be

saved by sprinkling the heap with *very* dilute SO_3 , or plaster, or by mixing it with dry muck, which will absorb the gas. If there is any copperas (produced by the oxydation of iron pyrites) in the soil, the lime will decompose it, forming gypsum and iron-rust ($\text{CaO}.\text{SO}_3 + \text{Fe}_2\text{O}_3$), thus changing a noxious ingredient into an element of fertility.

CARBONATE OF LIME.—This includes all varieties of common limestone, chalk, marble, marl, and forms the principal part of corals, shells, etc. Water charged with CO_2 absorbs carbonate of lime freely, which, when the gas escapes on exposure to the air, is deposited. In this manner, in limestone regions, the water trickling down into caverns has



A Cave.

formed “stalactites,” which depend from the ceiling, and “stalagmites,” that rise from the floor. These frequently assume most curious and grotesque forms, as in the Mammoth Cave. Around many springs, the water, charged with lime in solution, flows over moss or some vegetable substance, upon which the

lime is deposited. The spongy stone thus formed is calcareous tufa, or "petrified moss." *Whiting* is a carbonate of lime, made by grinding chalk. *Marble* is crystallized limestone. *Chalk* or *marl* is a porous kind of limestone, formed from beds of shells, but not compressed as in common limestone. These minute shells may be detected by a powerful microscope, even in glazing scraped from a common visiting card.

SULPHATE OF LIME (CaO.SO_3)—*Gypsum, Plaster, etc.*—This occurs as beautiful fibrous crystals in satin spar, as transparent plates in selenite, and as a snowy-white solid in alabaster. It is soft, and can be cut into rings, vases, etc. When heated it loses its water of crystallization, and falls into powder, called "Plaster of Paris," from its abundance near that city. Made into a paste with HO , it first swells up, and then immediately hardens into a solid mass. This property fits it for use in copying medals and statues, forming moulds, fastening metal tops on glass lamps, etc. Plaster is also used as a fertilizer. Its action is probably somewhat like that of lime, and in addition it gathers up ammonia and holds it for the plant. It is said that Franklin brought it into use by sowing it over a field of grain on the hill-side, so as to form, in gigantic letters, the sentence, "Effects of gypsum." The rapid growth produced soon brought out the words in bold relief, and decided the destiny of gypsum among farmers. *Sulphite* of lime (CaO.SO_2) should be distinguished from the sulphate (CaO.SO_3). This is used for preserving cider.

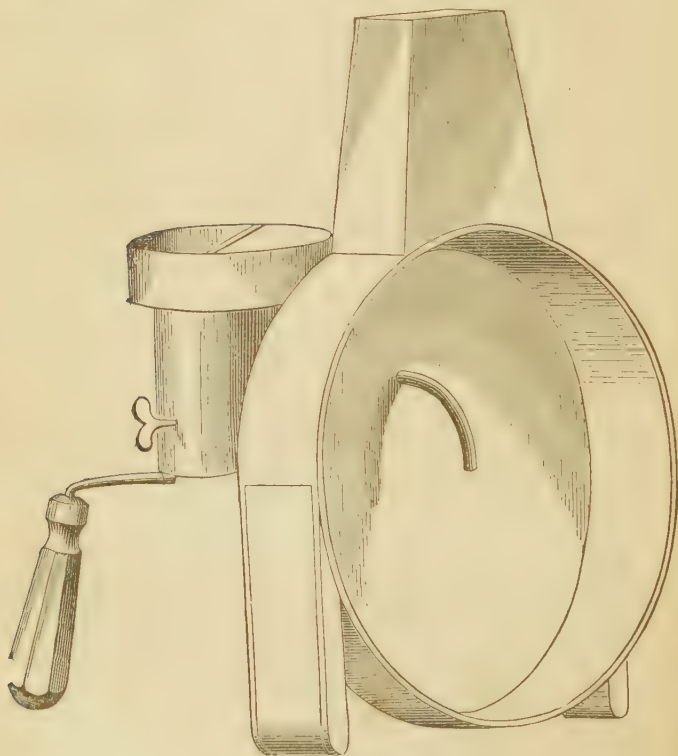
PHOSPHATE OF LIME is contained, as we have already seen, in bones. If now we add to them SO_3 , it will take up a part of the lime, making sulphate of lime (plaster), and the phosphoric acid thus driven off will take refuge with the rest of the acid and share its lime, forming a *super*-phosphate of lime. This is used very extensively as a fertilizer, and is, as we have described, a mixture of gypsum or plaster, lime, and phosphoric acid. The last furnishes phosphorus to the growing plant to store in its seeds. Example: Corn, wheat. Phosphate of lime and ammonia are the valuable constituents of "guano."

MAGNESIUM.

Symbol, Mg Equivalent, 12 Specific Gravity, 1.7.

Source.—Mg is found in many rocks as meerschauum, soapstone, and magnesian limestone, and is abundant also in sea-water. It gives to a stone a soapy feel. When pure, it has a silvery appearance and lustre. It is very light and tenacious as steel, while it is flexible as twine. It burns in the open air with a brilliant white light, casting dense shadows through an ordinary flame. This light possesses the actinic or chemical principle so perfectly, that it is used for taking photographs at night, views of coal-mines, interiors of dark churches, etc. It has every ray of the spectrum, and so does not, as does gas-light, change some of the colors of an object upon

which it falls. Lamps for burning it are very extensively made in Boston. By means of clockwork, the metal, in the form of a narrow ribbon, is fed in front



Magnesium Lamp.

of a concave mirror, at the focus of which it burns. The product of the combustion of Mg is MgO , the very substance from which the metal was obtained.

It is probable that the process of preparation will be cheapened, so that magnesium may be furnished at a rate which will bring it within the scope of the arts. It would be invaluable for lighting stores in which fancy goods are sold, or for illuminating large halls by means of a single lamp suspended in the dome.

CARBONATE OF MAGNESIA ($\text{MgO} \cdot \text{CO}_2$).—This is the “magnesia alba,” or simple magnesia of the druggists. By driving off the CO_2 , calcined magnesia is formed. Sulphate of magnesia is known as Epsom salt, from a celebrated spring in England in which it abounds.

METALS OF THE EARTHS.

These are Al, Gl, Zr, Y, Ce, La, D. All are extremely rare except the first.

ALUMINUM.

Sym., Al Equiv., 13.7 Spec. Grav., 2.5 Fusing Pt., 2283°.

This is commonly called the “clay-metal.” It is named from alum, in which it occurs. It is the metallic base of all clay, argillaceous, and granite rocks. It is a bright white metal, does not oxydize in the air, nor, like silver, tarnish by HS. It gives a clear musical ring; is lighter than glass, being only two and a half times as heavy as HO; is ductile, malleable, and more tenacious than Fe.

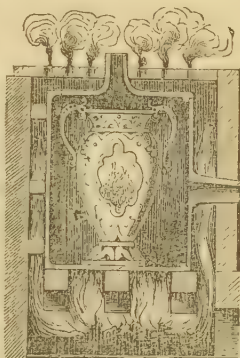
dissolves in HCl or in common vinegar, but is proof against SO_3 or NO_3 . On account of its abundance (every clay-bank is a mine of it) and useful properties, it must ultimately come into common use in the arts and domestic life.

ALUMINA (Al_2O_3).—Pure alumina, crystallized in nature, forms valuable Oriental gems. They are variously colored by the oxyds;—blue, in the sapphire; green, in the emerald; yellow, in the topaz; red, in the ruby. Massive impure crystals, when powdered, are called emery, and are used for polishing.

SILICATE OF ALUMINA ($\text{Al}_2\text{O}_3.\text{SiO}_2$)—*common clay*.—When the granite rocks decay, by the resistless and constant action of the air, rain, and frost, they crumble into clay. This gives firmness to the soil, and retains moisture, but is cold and tardy in producing vegetable growth. When free from iron, it is used for making tobacco-pipes. When colored by yellow or red oxyd of iron, it is known as ochre, and is employed in painting. Common stone and red earthen-ware are made from impure varieties of clay; porcelain and china-ware require the finest known. Fire-bricks and crucibles are made from a clay which contains much silica. Fullers' earth is a very porous kind, and by capillary attraction absorbs grease and oil from cloth.

Glazing.—When any article of earthenware has been moulded from clay, it is then baked. The ware is now porous, and would not even hold HO .

A mixture of the coarse materials from which glass is made is then spread over the vessel, and heated till it melts and forms a perfect glazing upon the clay. NaCl and sand form the glazing on stoneware, jugs, etc. PbO makes a yellowish glaze, which is very injurious, as it will dissolve even in vinegar, and form sugar of lead, a deadly poison. The color of pottery-ware and brick is due to the oxyd of iron present in the clay. Some varieties have no iron, and so form white ware and brick.



Baking Porcelain.

SULPHATE OF ALUMINA AND POTASH ($\text{KO} \cdot \text{SO}_3 + \text{Al}_2\text{O}_3 \cdot 3\text{SO}_3 + 24\text{HO}$).—Alum is formed by soaking clay with SO_3 , in large casks for several months, until the sulphate of alumina is formed, when potassa is added, and the whole mass becomes filled with crystals of the new salt. Instead of KO, other bases are sometimes used, and an iron, soda, or chrome alum is formed. When heated, alum loses its water of crystallization, froths up, and becomes a porous mass, known as “burnt alum.” Alum is soluble in 18 parts of cold water. It is much used in dyeing. It unites with the coloring matter, and binds it to the fibres of the cloth. It is therefore called a mordant (*mordeo*, to bite).

ALUM CRYSTALS.—Beautiful octahedral crystals

of alum are obtained by suspending threads in a saturated solution of this salt. In this manner alumbaskets, bouquets, etc., are made of any desired color.

SPECTRUM ANALYSIS.

Many of the metals named as rare have been lately discovered by what is termed Spectrum Analysis. We have already noticed that various metals impart a peculiar color to flame; thus the soda salts give a yellow tinge, copper a green, etc. If now we look at these colored flames through a prism, we shall find the "spectrum," or bands of rainbow-colors we are familiar with, strangely ornamented with bright-tinted lines. Thus the spectrum of sodium has one double yellow line; silver, two green lines; cæsium, a beautiful blue line. Each metal makes a distinctive spectrum, even when the flame is colored by several substances at once. This method of analysis is so delicate that $\frac{1}{250,000,000}$ of a gramme of sodium, or the $\frac{1}{50,000,000}$ of a gramme of lithium, can be detected in the flame of an alcohol lamp.

For the more perfect examination of the spectra, a "spectroscope" is used. This consists of a tube with a narrow slit at one end, which lets only a single ray of colored light fall upon the prism within, and **at** the other a small telescope, through which one can look in upon the prism and examine the spectrum.

THE HEAVY METALS.

IRON.

Symbol, Fe....Equivalent, 28....Specific Gravity, 7.8.

Iron is the symbol of civilization. Its value in the arts can be measured only by the progress of the present age. In its adaptations and employments it has kept pace with scientific discoveries and improvements, so that the uses of iron may readily indicate the advancement of a nation. It is worth more to the world than all other metals combined. We could dispense with gold or silver,—they largely minister to luxury and refinement, while iron represents only the honest industry of labor. Its use is universal, and it is fitted alike for massive iron cables, and for screws so tiny that they can be seen only by the microscope, appearing to the naked eye like grains of black sand.

“Iron vessels cross the ocean,
Iron engines give them motion,
Iron needles northward veering,
Iron tillers vessels steering,
Iron pipes our gas delivers,
Iron bridges span our rivers,
Iron pens are used for writing,
Iron ink our thoughts inditing,
Iron stoves for cooking victuals,
Iron ovens, pots, and kettles,
Iron horses draw our loads,
Iron rails compose our roads,
Iron anchors hold in sands,

Iron bolts and rods and bands,
 Iron houses, iron walls,
 Iron cannon, iron balls,
 Iron axes, knives, and chains,
 Iron augers, saws, and planes,
 Iron globules in our blood,*
 Iron particles in food,
 Iron lightning-rods on spires,
 Iron telegraphic wires,
 Iron hammers, nails, and screws,
Iron everything we use."

Its abundance everywhere indicates how indispensable the Creator deemed it to the education and development of man. There is no "California" of iron. Each nation has its own supply. No other material is so enhanced by labor. A bar of Fe, worth \$5, becomes worth, when made into horse-shoes, \$10; into needles, \$55; penknives, \$3,285; shirt-buttons, \$29,480; and in watch-springs, \$240,000, or more than its weight in gold.

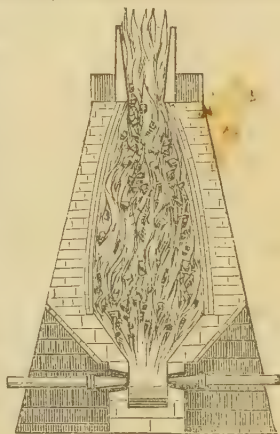
OXYDS OF IRON.—The most usual are: (1) **BLACK or MAGNETIC OXYD OF IRON** (Fe_3O_4), as found in the loadstone, Swedish iron ore, scales which fly off in forging iron, and in the iron mountains of Missouri. It is also seen in the thin pellicles overstanding HO, producing a beautiful iridescent appearance, the color changing with the thickness of the oxyd: (2) **The RED OXYD OF IRON—sesquioxyd—**(Fe_2O_3), as seen in

* There is not probably enough iron in the blood of a full-grown person to make a ten-penny nail, yet it gives energy and life to the system. Iron is given in the form of a fine powder, or a citrate of iron, as a tonic, and is a powerful remedy.

bog-iron ore, in the beautiful radiated and fibrous specimens of brown and red hematite, in bricks and pottery-ware, and in common iron-rust. The sesquioxyl, when combined with HO, forms (3) HYDRATED SESQUIOXYD OF IRON ($\text{Fe}_2\text{O}_3 \cdot \text{HO}$), and has a yellow color, which is changed to red by heat, when the HO is expelled, as in burning of brick, etc. These oxyds give the yellow and black colors seen in clayey soils and on the surface of weather-beaten stones. The black gradually oxydizes into the yellow, and so a black stone forms a yellow sand or soil.

Smelting of Iron Ores.—Iron is not found pure, but is locked up with O in an apparently useless stone. C is the key that is ready made and left for our use by the Creator. It only remains for us to apply it and turn the wards.

The process adopted at the mines is very simple. A tall blast-furnace is constructed of stone and lined with fire-brick. At the top is the door and at the bottom pipes for forcing in hot air, sometimes twelve thousand cubic feet per minute, by huge blowing-cylinders driven by steam-power. The furnace is filled with lime-stone, coal, and iron ore, in alternate layers, and the fire ignited. The C unites with



A Blast-Furnace.

the O of the ore, and goes off as CO_2 . The limestone forms, with the other impurities, silica, etc., a richly-colored glassy slag, which rises to the top. The melted iron runs to the bottom, and is drawn off into channels cut in the sand on the floor of the furnace. The large main one is called the *sow*, and the smaller lateral ones the *pigs*, and hence the term *pig-iron*.

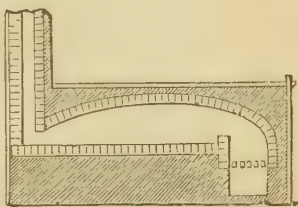
Properties.—Iron when pure is white. As commonly seen it has a gray tint, and is susceptible of a high polish. It is malleable and ductile. It has been beaten into leaves so thin that it has been used for writing-paper—six hundred leaves being only half an inch in thickness—and has been drawn into wire as fine as a hair. By constant jarring it tends to take a crystalline structure, becoming rotten and brittle, so that the axles of cars, cannon, etc., are condemned after a certain time, although no flaw may appear. It is an exception to the law that “cold contracts,” since at the instant of solidification it expands, so as to copy exactly every line of the mould in which it is cast. This fits it perfectly for castings. Almost the entire value of iron in the arts depends upon this fact. Otherwise we could never hammer out enough tools and machinery to keep the world at work. Was it chance or design that contrived all this nice planning so long even before man was made?

Varieties of Fe.—The usual forms of iron are *cast*, *wrought*, and *steel*. These depend upon the quantity of C they contain. A cwt. of cast-iron has about

5 lbs. of C, a cwt. of wrought about $\frac{1}{2}$ lb., and steel is between them in varying quantities.

CAST FE is the form in which it comes from the furnace. It is brittle, cannot be welded, and is neither malleable nor ductile, but is adapted for castings.

WROUGHT OR MALLEABLE FE is made by burning out the C from cast-iron, in a current of highly-heated air, in what is called a reverberatory furnace. The Fe is stirred up constantly, and exposed to the hot air by means of "long puddling-sticks," as they are termed, and then taken out and beaten under a trip-



A Reverberatory Furnace.

hammer to force out all the slag, and bring the particles of Fe nearer each other. It now takes on a fibrous structure, and can be welded, is malleable and ductile. It is hardened by being cooled rapidly, and softened by cooling slowly. The blacksmith tempers his work by plunging the article in cold HO.

STEEL contains less C than cast and more than wrought iron. It is therefore made from the former by taking out a part of the C, or from the latter by heating it in boxes of charcoal, and so adding C.* The value of steel depends largely upon the temper-

* By what is now known extensively as "Bessemer's process of making steel," it is formed from pig-iron without the use of fuel. A current of hot air is carried up through the liquid iron, which burns out the carbon, and in its combustion produces heat

ing quality it possesses. As the metal cools, the film of oxyd on the surface gradually thickens, and so deepens in color. By watching this the workmen know when the exact degree of hardness is reached. Knives require an orange, chisels a crimson, springs and swords a blue tint. Cheap knives made of soft iron are often covered with a superficial coating of steel. They are simply heated with charcoal a little time, so that the outside only becomes steelified, as it were. When we use such knives, we soon wear through this crust, and find soft iron beneath, which will take no edge. This is termed case-hardening.

Galvanized Fe.—This is formed by dipping sheets of iron in melted zinc, a thin layer of which adheres to the iron and prevents oxydation.

BISULPHURET OF FE (Fe S_2), *iron pyrites—fool's gold*; so called, because it is often mistaken by ignorant people for gold. It occurs in cubical crystals and bright shiny scales. It can be easily tested by roasting it on a hot shovel, when we shall catch the well-known odor of the S.

SULPHATE OF FE ($\text{FeO.SO}_3 + 7\text{HO}$)—*green vitriol, copperas*, made at Stafford, Connecticut, from FeS_2 , by exposure to air and moisture. It is formed in the

enough to continue the operation. When the iron is entirely *decarbonized*, enough iron, rich in carbon, called “*spiegeleisen*,” or “*looking-glass iron*,” is added to transform it into steel. At the conclusion, in less than twenty minutes commonly, the entire mass of tons weight is run out and cast into bars of the very best steel. This method has revolutionized the old modes of manufacture.

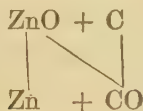
same manner in the decay of rocks, containing iron pyrites, and is found in the soil. Used in dyeing, making ink, and in photography.

Z I N C.

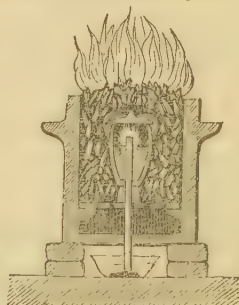
Symb. Zn....Equiv. 32.5....Spec. Grav. 7....Fusing Point, 470° F.

Source.—Zinc, or “spelter” as it is called in commerce, is found in ZnO, or red oxyd, in New Jersey, and as ZnS, or zinc blende, at many places.

Preparation.—ZnO is purified on the same principle as iron ore, by heating the powdered ore with C. The reaction is as follows :



Both these products distil as a vapor, and the Zn is condensed while CO escapes.



Roasting Zinc Ore.

Properties.—Ordinary Zn is brittle, but singularly enough, when heated to 200° or 300° F., it becomes malleable, and is rolled out into the sheet Zn in use so commonly. It burns in the air with a magnificent green light, forming great flakes of ZnO, sometimes called “Philosopher’s Wool.” Example: On a red-hot ladle sprinkle some powdered saltpetre and Zn filings. The KO.NO₃ will furnish O, and the metal will burn with great brilliancy. When exposed to

the air, Zn soon oxydizes, and the thin film of white oxyd, formed over its surface, protects it from further change.

Uses.—It has many economic uses, known to all. The oxyd, ZnO, is sold as zinc-white, and is much valued as a paint, since it is not deleterious to the painters, and does not blacken by HS like white-lead. The sulphate, ZnO.SO₃ (white vitriol), is a powerful emetic.

T I N.

Symb. Sn....Equiv. 56....Spec. Grav. 7.2....Fusing Point, 420° F.

Sn is found mainly in Cornwall, England, in Jackson, New Hampshire, in slight quantities, and in Missouri. It is not ductile, but is very malleable, so that tin-foil is not more than $\frac{1}{1000}$ of an inch in thickness. When quickly bent, it utters a shrill sound, called the "tin cry," caused by the crystals moving upon each other. The tendency of Sn to crystallize is remarkable. Example: Heat a piece of Sn till the coating begins to melt; then cool quickly and clean it in aqua-regia. The surface will be found to be covered with beautiful crystals of the metal. Ordinary tin-ware is formed by dipping sheet-iron in melted Sn, which produces an artificial coating of the latter metal. If we leave HO in a tin dish long, the yellow spots betray the presence of Fe. Tin does not oxydize at ordinary temperatures. SnO₂, sold as *putty powder*, and used for white

enamel and for polishing glass, is formed by the action of NO_5 on Sn. Example: Pour a little dilute NO_5 on scraps of tin, and watch the evolution of nitrous acid fumes, and the formation of SnO_2 . SnS_2 is the ordinary mosaic gold used in printing the bronze letters and figures on handbills and wall-paper. Pins are made of brass wire, and then boiled with tin and cream of tartar. This gives a bright white surface to the metal. The pins are stuck in papers, as we see them, by machinery which picks them up out of a miscellaneous pile, counts them, and inserts them in the paper, complete for the market. The first part of the process is performed by a sort of coarse comb, which is thrust into the heap, and gathers up a pin in each of the spaces between the teeth.

COPPER.

Symb. Cu....Equiv. 31.7....Spec. Grav. 8.9....Fusing' Pt. 1996° F.

Sources.—Found native near Lake Superior, frequently in masses of great size. In these mines are discovered stone hammers, the tools of a people more ancient than the Indians, who probably occupied this continent, and worked the mines. In the Western mounds copper instruments are found *Malachite*, $\text{CuO} \cdot \text{CO}_2$, is the best known ore of copper. It is found in Siberia, and is worked into beautiful ornaments, much prized by the Russian nobles.

Properties.—It is ductile, malleable, and a con-

ductor of electricity. Its vapor gives a characteristic and beautiful green color to flame. It is hardened by hammering, and softened by heating and plunging into cold HO,—just the reverse of iron, which fact spoils all our good theories as to the cause in either case. In a damp atmosphere, the CO_2 unites with it, forming $\text{CuO} \cdot \text{CO}_2$, familiarly but improperly called *verdigris*. The *true verdigris* is *acetate of Cu()*, and is produced when we soak pickles in brass or copper kettles; the green color which results is simply this salt—a deadly poison. Preserved fruits, etc., should never stand in such vessels, as the vegetable acids dissolve Cu readily. The black coating which collects on copper or brass kettles is the black oxyd of copper, CuO , and very poisonous. It dissolves readily in fats and oils. Such utensils should therefore be used only when perfectly bright, and then never with any fruits, sweetmeats, jellies, pickles, etc. NO_5 is the solvent of Cu. Its test is NH_3 , forming in a solution a pale blue precipitate, which dissolves in an excess of the reagent.

SULPHATE OF COPPER ($\text{CuO} \cdot \text{SO}_3 + 5\text{HO}$)—*blue vitriol*—is much used in dyeing, calico printing, and galvanic batteries.

LEAD.

[Sym., Pb Equiv., 103.6 Spec. Gr., 11.44 Fusing Pt., 612°F .

Sources.—Its most common ore is galena, a sulphuret (PbS), which is reduced by roasting in a re-

verberatory furnace. The S burns and leaves the metal.

Properties.—It is malleable, but contracts as it solidifies, so it cannot be used for castings. It is poisonous, though not immediately, as bullets have been swallowed, and then thrown off without any harm except the fright. Its effects seem to accumulate in the system, and finally to manifest themselves in some disease. Persons who use lead, as painters and plumbers, after a time suffer with colics, paralysis, etc. It is much used for water-pipes, and is the most convenient of any metal for that purpose. Pure water passing through the pipe will not corrode the lead, but the O of the air it contains forms an oxyd of lead which dissolves in the HO. If there are any sulphates or carbonates in the HO, these will form a coating over the lead, and protect it from further corrosion; and as carbonate of lime is common in all hard water, that is safe. If, when we examine a lead pipe that is in constant use, we find it covered with a white film, that is a good sign; but if it is bright, there is cause for alarm. Still, however much may be said upon the danger, people will use lead pipes, and the following precautions should be observed: *Always let the water run long enough in the morning before using, to remove all which has remained in the water-pipes during the night, and after the HO has been drawn off for awhile, when it is let on again, leave the faucet open until the pipe is thoroughly washed.*

OXID OF LEAD (PbO) is the well-known *litharge*, and is used in glass-making, in paints, and in glazing earthenware, as we have elsewhere described.

MINIUM, or *red-lead* (Pb_3O_4), is used for coloring sealing-wax red, and as a paint.

CARBONATE OF LEAD ($\text{PbO} \cdot \text{CO}_2$).—*White-Lead*.—This salt is made in large quantities in the following manner. Thousands of earthen pots fitted with



A — An earthen pot.
L — A coil of lead.
V — A solution of vinegar.

covers are filled with weak vinegar (acetic acid) and a small roll of lead, arranged in immense piles, and then covered with tan-bark. The acetic acid combines with the lead, but the CO_2 formed by the decomposing tan-bark creeps in under the cover, driving off the acetic acid, and forming carbonate of lead. The acetic acid, thus dispossessed, attacks another portion of the lead, but is robbed again; and so the process goes on, until at last all the lead is exhausted. White-lead is largely adulterated with sulphate of baryta—heavy spar. This can be easily detected by digesting (gently heating) a little in NO_3 , or even in strong vinegar, which will form a soluble nitrate or acetate of all the lead in the paint, while the baryta will settle to the bottom as a white precipitate.

ACETATE OF LEAD ($\text{PbO} \cdot \text{A}$).—*Sugar of Lead*.—This salt has a sweet, pleasant taste, and has been frequently taken by mistake, owing to its being in such common use. It is a virulent poison. The antidote is Epsom salt, which forms an insoluble sulphate

of lead. Water dissolves it readily. Ex.: If a piece of zinc, cut in small strips, be suspended in a bottle filled with a solution of this salt, the lead will be deposited upon it by voltaic action in beautiful metallic spangles, forming the "lead-tree."



The Lead-tree.

Test of Pb.—This is HS, which forms with the metal the black sulphuret of lead (PbS). A very amusing illustration is as follows: Thicken a solution of $\text{PbO} \cdot \bar{\text{A}}$ with a little gum-arabic, so as not to flow too readily from the pen, and then make any sketch which your fancy may suggest. This, when dry, will be invisible. When it is to be used, dampen the paper slightly on the wrong side, and then direct against it a jet of HS, and the picture will blacken into beauty.

ARSENIC.

Symbol, As....Equivalent, 75....Specific Gravity, 5.8.

Volatilizes without fusion at 356°F .

This is a brittle, steel-gray metal, commonly sold when impure as *Cobalt*. If heated in the open air it gives off the odor of garlic, which is a test of As.

ARSENIOUS ACID (AsO_3).—This is the well-known "*ratsbane*," and is sometimes sold as simply "*arsenic*."

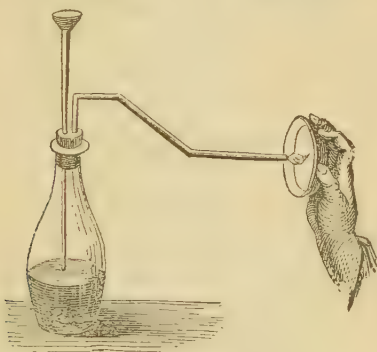
Preparation.—It is made in Silesia, by roasting arsenical iron ore at the bottom of a tower, above which is a series of rooms through which the vapors

ascend, and pass out through a chimney at the top. The As burns, forming AsO_3 , which collects as a white powder on the walls and floors of the chambers above. Its removal is a work of great danger. The workmen are entirely enveloped in a leathern dress and mask with glass eyes; they breathe through a moistened sponge, thus filtering the air of the fine particles of arsenic floating through it. Yet, in spite of all these precautions, the workmen rarely live beyond forty.

Properties.—Arsenious acid (arsenic) is soluble in hot HO , and has a slightly sweetish taste. It is a powerful poison, doses of two or three grains being fatal, although an over-dose acts as an emetic. It is an antiseptic, and so in cases of poisoning frequently attracts attention by the perfect preservation of the body, even twenty or thirty years after the murder has been committed. The antidote is milk, whites of eggs, or soapsuds (the latter being good in almost any case of poisoning), taken *immediately*. The exact chemical antidote is the hydrated sesquioxyl of iron, prepared by adding an alkali to a solution of copperas ($\text{FeO} \cdot \text{SO}_3$). The bulky precipitate soon reddens by the absorption of O from the air, and becomes the sesquioxyl. It must be perfectly fresh and moist to be of any value.

MARSH'S TEST.—There is no other poison which is so easily detected. Prepare a flask for the evolution of H. Ignite the jet of gas, and hold in the flame a cold porcelain dish. If the materials contain no

As, it will remain untarnished. Now pour in through the funnel-tube a few drops of a solution of As (made by dissolving a little AsO_3 in HCl), and the color of the flame will be seen to change almost instantly, and a copious "metallic mirror" of As will be deposited on the dish. The gas formed in this experiment—arsenuretted hydrogen—is very poisonous indeed, and the utmost care should be used to prevent its inhalation. In a case of poisoning, of



Marsh's Test.

course, the contents of the stomach would be substituted for the solution of As, and many other tests besides this would be employed. We can imagine with what care a chemist would conduct this test, and with what intense anxiety he would watch the porcelain dish as the flame played upon it, hesitating, and dreading the issue, as he felt the life of a fellow-being trembling on the result of his experiment.

Arsenic-eating.—It is said that the peasants in

portions of Hungary are accustomed to eat As, both fasting and as a seasoning to their food. A very minute portion will warm and stimulate and aid in climbing lofty mountains. The arsenic-eaters are described as plump and rosy, and it is said that the young people resort to it as a species of cosmetic to make them more attractive. They begin with small doses, which are gradually increased; but if the person should cease the practice at any time, all the symptoms of arsenic poisoning immediately appear. Horse-jockeys are said to feed arsenic to their horses to improve their flesh and speed.

CHROMIUM.

Symbol, Cr.

This element is commonly known as combined with O in chromic acid, CrO_3 . The ruby owes its beautiful red to this acid. Bichromate of potassa, $\text{KO} \cdot 2\text{CrO}_3$, is a red salt, much used in the laboratory, dyeing, etc. Example: If we mix a solution of this salt and one of sugar of lead, a yellow-colored precipitate will be formed, known as chrome yellow ($\text{PbO} \cdot \text{CrO}_3$), valued in painting and dyeing. Ex.: Moisten a piece of flannel in a solution of sugar of lead ($\text{PbO} \cdot \bar{\text{A}}$), then in one of Glauber's Salt ($\text{NaO} \cdot \text{SO}_3$), to change the acetate of lead to a sulphate of lead, and lastly, in one of bichromate of potash, when the cloth will be found to be dyed a permanent yellow.

THE NOBLE METALS.

These are: Mercury, Silver, Gold, Platinum, Palladium, Iridium, Osmium, Ruthenium, Rhodium.

MERCURY.

Symbol, Hg....Equivalent, 100....Specific Gravity, 13.5.

Freezes at -39° F....Boils at 662° F.

Mercury is also called quicksilver, because it runs about as if it were alive, and was supposed by the alchemists to contain silver. It was known very anciently, and the mines of Spain were worked by the Romans.

Source.—Cinnabar, HgS , a brilliant red ore, called also “vermilion,” is the principal source of this metal. Hg is found native in Mexico in very small quantities, where the mines are said to have been discovered by a slave, who, in climbing a mountain, came to a very steep ascent. To aid him in surmounting this, he tried to draw himself up by a bush which grew in a crevice above. The shrub, however, giving way, was torn up by the roots, and a tiny stream, of what to him seemed liquid silver, trickled down upon him.

Properties.—Mercury emits a vapor at all temperatures above 40° F. Its solvent is NO_5 . It is the only element, except bromine, that is fluid at ordinary temperatures. It forms an amalgam—a union

of Hg and a metal—viz., gold or silver. We should therefore never touch a gold ring, for instance, to Hg, as it will cover it immediately with a thin film of this amalgam.

Uses.—Hg is extensively employed in the manufacture of thermometers, barometers, for silvering mirrors, and extracting the precious metals from their ores. The well-known *blue-pill* is Hg incorporated with chalk and flavored with liquorice. *Mercurial ointment* is Hg and lard well rubbed together. It is often called “anguintum,” which may be a corruption of the Latin term unguentum (unguent.) Hg is extensively employed in medicine, as calomel, Hg_2Cl , a subchloride of mercury. This can be distinguished from any other substance for which it is liable to be mistaken, especially corrosive sublimate, from the fact that it is insoluble in HO, and perfectly tasteless. The action of Hg on the human system is too well known to need description. “In its metallic state, Hg has been taken with impunity in quantities of a pound weight” (*Am. Cyc.*), but when finely divided, as in vapor or “blue-pill,” its effects are marked. It renders the patient extremely susceptible to colds, acts directly upon the liver, increasing the secretion of bile, and in over-doses produces “salivation.”

RED OXYD OF Hg, “red precipitate,” is interesting, as the substance from which Priestley discovered O gas.

CHLORIDE OF Hg (Hg.Cl), “corrosive sublimate,” is

well known to housekeepers. It is a heavy, white solid, soluble in HO, and with a burning metallic taste. It has powerful antiseptic properties, and is used to preserve specimens in natural history. It is a deadly poison, and its antidote is white of eggs, milk, etc.

Mirrors were anciently made of steel or silver, highly polished. They were very liable to rust and tarnish, and so a piece of sponge, sprinkled with pumice-stone, was suspended from the handle for rubbing the mirror before use. Seneca, in lamenting over the extravagance of his day among the old Romans, says: "Every young woman now-a-days must have a silver mirror." The process of silvering ordinary mirrors is as follows. Tinfoil is first spread evenly upon the glass, and then the Hg is carefully poured over it. The two metals combine, forming a bright amalgam, which clings to the glass. The superfluous Hg is cautiously wiped or pressed off. When we look into a mirror we rarely realize what it has cost others to thus minister to our comfort. The workmen are short-lived. A paralysis sometimes attacks them within a few weeks after they enter the manufactory, and it is thought remarkable if a man escapes for a year or two. Its effects are similar to those we have just spoken of when treating of calomel; the patient dances instead of walks, he cannot direct the motion of his arms, nor in some cases even masticate his food.

IRIDIUM.

Symbol, Ir Equivalent, 99 Specific Gravity, 21.15.

This metal is named from Iris, the rainbow, because of the beautiful color of its salts in solution. It is the heaviest of the elements, being over 21 times as heavy as water. When combined with Osmium, it makes "iridosmine," well known as the points of gold pens.

PLATINUM.

Symbol, Pt Equivalent, 98.6 Specific Gravity, 21.
Fusing Point, 4591° F.

Source.—Platinum is chiefly found in the Ural Mountains, where it occurs in alluvial deposits, in small, flattened grains.

Properties.—It resembles Ag in its appearance. It is the most ductile metal known, wire having been made from it so fine as to be invisible to the naked eye.* It is soluble in aqua-regia, but not in the simple acids. It does not oxydize in the air, is the most infusible of metals, and can be melted only

* Wollaston's Method, as it is called, consists in covering fine platinum wire with several times its weight of silver, and then drawing this through the plates used for drawing wire until the finest hole is reached, when the wire is placed in NO_3 , which dissolves the Ag and leaves the Pt intact. This, in the form of the finest wire known, may be found in the solution by means of a microscope. A single ounce of Pt, it is said, will make a wire that would reach from New York to New Orleans.

by the heat of the compound blow-pipe or voltaic battery. In the arts it is fused in the former manner. These properties fit it for use as crucibles in the laboratory, and for this purpose it is invaluable to the chemist.

GOLD.

Symbol, Au Equivalent, 196.4 Specific Gravity, 19.34.
Fusing Point, 2016° F.

Sources.—Gold is widely diffused. It occurs sometimes in cubes, in masses called nuggets, and is always native. It is found generally in small grains, or scales, scattered through the rocks. As these disintegrate by the action of the elements, the gold is gradually washed into the valleys below, and thence into the streams and rivers, where, owing to its specific gravity, it settles and collects in the mud and gravel of their beds. In this way we trace the origin of the extensive gold-plains of California.

Preparation.—As the metal is thus found native, the process is purely mechanical, and consists simply in washing out the dirt and gravel in wash-pans, rockers, etc., at the bottom of which the metal accumulates, the only requisites being these tools and an abundance of water. In the quartz-mills the rock is thrown into great troughs of water, in which, by heavy stamps, the ore is crushed to powder. As the thin liquid mud thus formed splashes up on either side, or is conducted from the stamping-mill, it runs

over broad metallic tables covered with mercury. This unites with the little particles of gold as they are washed along, and forms with them an *amalgam* (a compound of mercury and a metal). From this the gold is easily separated by distillation, and the mercury collected to be used again.

QUARTATION.—Gold is sometimes alloyed with silver. In that case the silver is dissolved out by NO_3 . There must be three parts of silver to one of gold, else the gold will protect all the silver from the action of the acid. If there is not so much, some is added.

Properties.—Pure gold is nearly as soft as lead. It is extremely malleable and ductile. Its solvent is aqua-regia. It does not oxydize at any temperature.

GOLD-LEAF.—The process of making gold-leaf is very simple. The metal is first rolled into thin ribbon, and then divided into pieces one inch square. These are placed, one by one, between leaves of gold-beaters' skin and hammered until they are beaten four inches square, when they are subdivided into four pieces. (See Phil, page 29). These are hammered as before, and the process repeated until the required thinness is obtained.

SILVER.

Symb., Ag....Equiv., 108....Spec. Gr., 10.5....Fusing Pt., 1873° F.

Sources.—Silver is found throughout the great West in a distracting variety of forms—most com-

monly however, combined with S, as *black sulphuret*, AgS ; with Cl, forming *horn-silver*, AgCl ; with S & As or Sb making *ruby-silver*, and also associated with lead in ordinary galena.

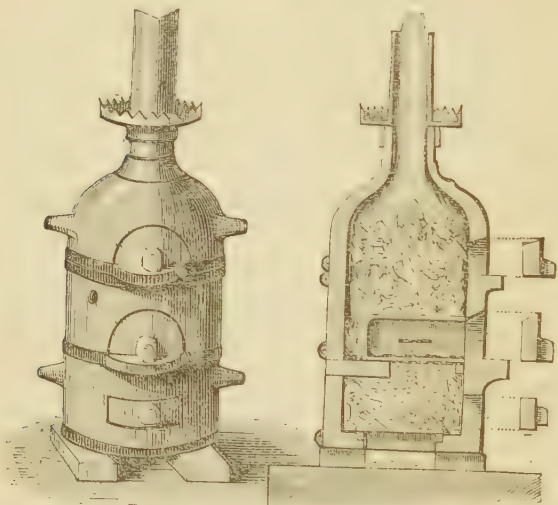
Preparation.—1st. The *sulphuret* is refined as follows. The ore is crushed into fine powder and then roasted with common salt. The Cl of the salt unites with the Ag, forming chloride of silver, AgCl . This is now put into a revolving cylinder with HO, Hg, and iron-scrap. The iron takes the Cl away from the silver, and the Hg catches it up, thus forming an amalgam of Hg and Ag. From this the silver is easily obtained, as in gold-washing. 2d. From *horn-silver*, AgCl , the process is like the latter part of that we have just described. 3d. From *lead* the silver can be profitably obtained even when there is not more than ten ounces in a ton. The alloy of the two metals is melted and then slowly cooled. Lead solidifies much sooner than silver, and by skimming out the crystals of Pb as fast as formed, they may be almost entirely separated. (See app. p. 252).

Cupellation.—A cupel is a shallow vessel, made of bone-ashes. In this the silver, debased with lead and other impurities, is placed and exposed to a red heat, so as to melt the metals, while a current of hot air plays upon the surface. The lead oxydizes, is changed to litharge, PbO , and is absorbed by the porous cupel. The mass appears soiled and tarnished, but the refiner keeps his eye



A Cupel.

upon it as the process continues, watching eagerly, until at last there is a brilliant play of colors—he catches his own image in the perfect metallic mirror, and the little “button” of pure silver lies gleaming at the bottom.* This must now be immediately removed, or it will oxydize and waste.



Cupels in Furnace.

Properties.—Silver is the whitest of all the metals. It is malleable and ductile. It expands at the moment it solidifies, and, therefore, can be cast. It has a powerful attraction for sulphur, forming the black sulphuret of silver. The perspiration from our bodies contains more or less S, and this, as it

* Malachi, iii. 3.

passes through our pockets, fraternizes with any silver we may chance to have there. Silver spoons and door-knobs are tarnished by the minute quantity of HS present in the air. Those who have visited any sulphur springs know the propriety of carefully protecting their gold or silver watches, and of never carrying them to the hot baths. AgS is very easily dissolved by a little *dilute* ammonia (1 part of NH_3 to 10 of HO), which is therefore used for cleaning silver door-knobs. The solvent of Ag is NO_5 . The test of silver in solution is HCl, which forms a cloudy precipitate of chloride of silver, AgCl. A solution of silver coin is blue, from the copper it contains.

NITRATE OF SILVER ($\text{AgO}.\text{NO}_5$).—It is sold in crystals, and also in sticks as *lunar caustic*. It is used as a cautery. It stains the skin and all organic matter black, owing to its decomposition by the light and the formation of oxyd of silver, AgO. A very pretty experiment, illustrating this, is performed by dropping into a test-tube of HO a few drops of nitrate of silver in solution, and then adding KO: a copious precipitate of AgO will fill the tube. At last add a little NH_3 , and it will instantly dissolve the brown oxyd, and leave the solution as clear and sparkling as spring-water. The stain from nitrate of silver may be removed by a solution of cyanide of potassium. Hair-dyes and indelible inks consist mainly of this salt of silver.

THE ALLOYS.

These are very numerous, and many of them possess properties so different from their elements that they almost seem like new metals. Their color and hardness are changed, and sometimes the melting point is below that of any one of the constituents.

Type Metal contains 3 parts lead to 1 of antimony.

Britannia consists of 100 parts tin, 8 antimony, 2 bismuth, and 2 of copper.

Brass is 4 parts of copper and 3 of zinc.

German Silver contains copper, zinc, and nickel—(brass whitened by nickel).

Soft Solder, used by tinsmiths, is made by melting lead and tin together, the usual proportion being half and half. Before putting on the solder, they moisten the surface of the metal with HCl , which dissolves the coating of the oxyd.

Hard Solder is composed of copper and zinc.

Fusible Metal melts at 203° , and spoons made of it will fuse in hot tea. It can be melted in a paper crucible over a candle. It consists of bismuth, lead, and tin. Yet the first metal melts at 476° , the second at 600° , and the third at 442° .

Bronze is 90 parts copper and 10 of tin.

Gold is soldered with an alloy of itself and silver; *Silver*, with itself and copper; *Copper*, with itself and zinc: the principle being that the metal of lower fusing point causes the other to melt more easily.

COIN.—The precious metals, when pure, are too soft for common use. They are therefore hardened by other metals. Gold coin consists of 9 parts gold and 1 of alloy. The alloy is composed of 9 parts of copper, whitened by one of silver, so as not to darken the gold coin. Silver coin is 9 parts silver and 1 of copper. The nickel cent is 88 parts copper and 12 of nickel. The object of the copper is to make the coin larger, as it is cheaper than nickel. The term carat, applied to the precious metals, means $\frac{1}{24}$ part. Therefore, gold 18 carats fine, contains $\frac{18}{24}$ of gold and $\frac{6}{24}$ of alloy.

SHOT is an alloy of about 1 part arsenic to 100 of lead. The manufacture is carried on in what are called “shot-towers,” some of which are two hundred and fifty feet high. The alloy is melted at the top of the building, and poured through colanders. The metal, in falling so far, breaks up into drops, which take the “spheroidal form,” harden, and are caught at the bottom in a well of water, which cools the shot and also prevents their being bruised in striking. The shot are dipped out, dried, and then assorted, by sifting in a revolving cylinder, which is set slightly inclined and is perforated with holes, increasing in size from the top to the bottom. The shot being poured in at the top, the small ones drop through first, next the larger, and so on, till the largest reach the very bottom. Each size is received in its own box. Shot are polished by being agitated for several hours with black-lead, in a rapidly

revolving wheel. The shot are finally tested by rolling them all down a series of inclined planes placed at a little distance from each other. The spherical shot will jump from one plane to the next, while the imperfect ones will fall short, and drop below; or sometimes, by rolling down a single inclined plane, the spherical ones will go to the bottom, while the imperfect ones roll off at the sides.

OREIDE—a beautiful alloy, resembling gold—is made at Waterbury, Connecticut. It is a French discovery. It consists of 100 parts copper, tin 17 parts, magnesia 6 parts, sal-ammoniac 3.6 parts, lime 1.8 parts, cream of tartar 9 parts. It can be beaten into leaves, cast, chased, rolled, and stamped like gold, while none but the most experienced judges can detect the difference.

ALUMINUM alloys with copper are becoming valuable, as Al is itself better known. They are elastic, malleable, and very light.

ORGANIC CHEMISTRY.

INTRODUCTION.

WE have thus far spoken of the various elements of matter. We have found "dead, mineral matter," as we commonly call it, all alive with desire and power. Each tiny atom has revealed to us a force that repelled it here, attracted it there, and held it to its place as with bands of iron. We have traced, through all the varied changes of matter, the workings of one law and one system, and have everywhere discovered our comfort and happiness to be the final end of creation. We have found the nicest cutting and planning, whereby each element appears fitted to its place in nature, as a skilful mechanic adapts one cog to another through a great series of machinery. No particle of matter seems left to itself, but, watched by the Eternal Eye and guided by the Eternal Hand, obeys immutable law. When Christ declared the very hairs of our head to be numbered, he intimated a chemical truth, which we can now know in full to be, that the very atoms of

which each hair is composed are all numbered by that same watchful Providence.

We have found the elements of the growth of our bodies, but still we cannot live upon them. We need phosphorus, but we cannot eat it; it would burn us to a coal. We need iron, but it would make a most unsavory diet. We need lime, but it would corrode our flesh. We need H, but it must be combined with O as HO to be of any value to us. If we were shut up in a room with all the elements of nature, we not only could not combine them so as to produce any of those organic substances necessary to our life and comfort, but we would actually die of starvation. We thus see that the mineral matter must be assimilated in some manner before we can use it to advantage. Here appears the object of the vegetable world. It turns *inorganic* matter into *organic*. The plant taking those elements which we need for our growth and for use in the arts and sciences, combines them into plant products, such as wood, starch, sugar, coal, etc.: we using these, live, grow, and develop into civilized man, fitted for all the grand achievements of life.

How strange it is that we are thus dependent upon plants! We know they decompose the poisonous CO₂, and give us our supply of the inspiring O, but that is only a part of our demands; they furnish us with all the grand staples of commerce, of luxury—all we eat, or drink, or wear. Each tiny leaf we see, each spire of grass is thus incessantly working

throughout the livelong day to meet our constant wants.

The object of ORGANIC CHEMISTRY is to treat of these plant-products and the various substances derived from them. Organic bodies differ from inorganic in several points.

1st. While inorganic bodies deal with 65 elements, organic are composed principally of only four, C, H, O, N—which are therefore called “ORGANOGENS”—and a very little mineral matter constituting the ash.

2d. While inorganic bodies consist of only a few atoms, and are therefore very simple in their construction (Ex.: HO, CO₂, KO), organic contain a large number, and are extremely complex. Ex.: Sugar = C₁₂H₁₂O₁₂; Oil of cedar = C₃₂H₃₆O₂; Fibrine = C₄₀₀H₃₁₀N₅₀O₁₂₀PS.

3d. While inorganic bodies are formed and remain fixed in one state under the influence of chemical affinity, organic grow rapidly, change constantly, and when life ceases, as rapidly decay, and are transformed into inorganic substances.

4th. Owing to their complex structure, and the presence in very many of the negative N, they form most unstable compounds. In this we see the reason of their rapid decay. The vital principle alone holds them together, frequently in opposition to the laws of chemical affinity; and the instant that is removed, the tendency is to seek new affinities and form new compounds.

NUMBER OF ORGANIC BODIES.—This is almost endless, and yet is constantly increasing. The labor of modern chemists is largely devoted to this subject, and the field opens and broadens with every discovery. The methods of classification are unsettled, and new and conflicting theories yet contend on this border-ground of chemical knowledge. Various organic bodies are now formed artificially by the skill of the chemist, and many others are broken up into simpler forms. Ex.: Alcohol = water and carburetted hydrogen.

ISOMERISM.—Isomeric compounds are those that consist of the same elements in the same proportion. Ex.: Heavy carburetted hydrogen, petroleum, oil of roses, and caoutchouc, consist alike of C_4H_6 . So that the fragrant odor of a rose, and that which comes from a petroleum lamp, contain precisely the same elements. Isomerism is supposed to be caused by a different grouping of the atoms about each other, as the same pieces upon a checker-board may be differently arranged.

ALLOTROPISM.—Not only may the same elements be thus differently grouped, and produce different compounds, as p-l-e-a may spell also l-e-a-p, or p-e-a-l, or p-a-l-e, but also the individual elements are susceptible of allotropic states; as, for instance, the C in a compound may be in any one of its three allotropic forms. These two principles of isomerism and allotropism run through organic chemistry, and

readily account for the inexhaustible variety of its compounds.*

STARCH ($C_{12}H_{10}O_{10}$).

Source.—Plants accumulate it in their roots—Ex., Carrot, turnip: in subterranean stems—Ex., Potatoes, of which it forms 20 per cent.: in the base of leaves—Ex., Onion: in the seed—Ex., Corn, of which it forms 80 per cent: in the embryo—Ex., Bean, pea. In all these it is stored up for the future growth of the plant or the seed. It is kept in its starch form (lest it dissolve in the first rain), and then turned to sugar only when and as the plant needs it in growing. The accompanying figures show the form of the grain of starch in a potato, as seen under the microscope, each vegetable having its peculiar shape, so that in this way any adulteration is easily detected.



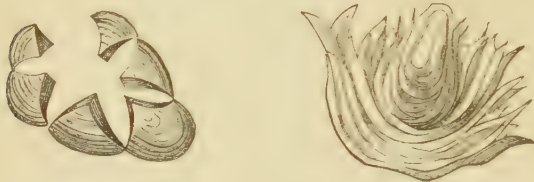
Starch Grain.

The potato, for example, is ground to a pulp, and

Preparation.—It is made from wheat, corn, potatoes. The process is essentially the same in all. The potato, for example, is ground to a pulp, and

* See ORGANIC CHEMISTRY, in Appendix.

then washed with cold water. The starch settles from this milky mass as a fine white precipitate.



Properties.—It is insoluble in cold water. If heated it absorbs water, swells, and the starch granules burst, forming a jelly-like liquid, used for what is known as *starching*. The swelling of rice, beans, etc., when cooked, is owing to this property. By heat, starch undergoes a peculiar change into a substance known as dextrine, or British gum, used for making envelopes, wall-paper, “fig-paste,” and for stiffening chintzes. The test of starch is iodine, which forms in solution a beautiful blue iodide of starch. Sago is the starch from the pith of the palm-tree; tapioca and arrow-root are made from the roots of South American marshy plants. Very many of the farinaceous preparations sold for the sick and invalid, under high-sounding names, are simply wheat or corn starch, put up in fancy papers and gilt lettering.

GUM ($C_{12}H_{10}O_{10}$).—This includes a variety of substances which exude from the bark of trees. **Ex.:** Cherry, plum. Gum-arabic is derived from an **Aca-**
cia tree.

PECTIC ACID, OR PECTINE.—This is a variety of gum existing in certain fruits, as the currant, apple, etc., which forms the vegetable jelly so much used as a sweetmeat. In the fully ripened fruit, this turns to sugar, and hence, as every housewife knows, a jelly cannot be made from the fruit except at a certain stage in the ripening process.

CELLULOSE, LIGNINE, ETC. ($C_{12}H_{10}O_{10}$).—Woody fibre is found in various modifications—in the heart of a tree, in shells of nuts, and stones of fruits. Its cells, filled with lignin, are hard and compact; in the sapwood, its cells, open and full only of sap, are soft and porous; in elder-pith and cork, they are light; in flax and cotton, pliable; in the bran of wheat and corn, very digestible. It composes the cells of all plants, giving them strength and firmness, and is found even in delicate fruits, holding their luscious juices.

Secretion.—All vegetation consists of these simple cells. They seem alike to the eye, yet they have a wonderful power of secretion. The cell of the sugar-maple converts the sap into sugar—the milk-weed, into a milky juice—the caoutchouc, into rubber; the pie-plant manufactures oxalic acid, and the rose-petal the most delicate of perfumes. Then again they are true to themselves. There seems to be a law of God stamped on each cell, so that when we cut a tiny bud from a tree and graft it into another, it remains consistent with itself. It develops into a limb, and years pass by—the few single cells become a myriad, yet

they have changed not. The sap flows upward in the tree; but at a certain point—a hidden threshold which no human eye can discern—it comes under a new and strange influence. It is here transformed, and produces fruit and flowers, in accordance with this new law. Somehow quince-juice is made into pears, locust-juice blooms out into fragrant acacias, while sweet apples and sour apples hang “cheek-by-jowl” on the same limb.

Uses.—These are wonderfully various. Woody fibre is woven into cloth, built into houses, twisted into rope, twine, and thread, cut into fuel, carved into furniture. We eat it, wear it, walk on it, write on it, sit on it, print on it, pack our clothes in it, sleep in it, ride in it, and burn it.

Curious Discovery.—It has lately been found that, by feeding the roots of a tree with some coloring matter, the wood of the trunk may be stained to imitate any color desired. In this way, common pine or maple takes the appearance of the rarest wood—mahogany, rosewood, etc.

PAPER is made from rags of all kinds, straw, or indeed almost any substance containing cellular tissue. The finest writing-paper is manufactured from the best of linen rags, brought from Italy. The rags are first shredded upon scythe blades—*i. e.*, the seams are ripped open, buttons cut off, and the dust shaken out. 2d. They are steamed in a solution of chloride of lime for ten or twelve hours until they are *thoroughly bleached*. 3d. They are received

by a machine that alternately lacerates them by a cylinder set with razor-like blades, and washes them with pure cold water for six hours, or until they are reduced to a mass resembling rice and milk. 4th. This mass receives a delicate blue tint from *smalt*—powdered glass colored with oxyd of cobalt. 5th. It is diluted with HO to the consistency of city milk, and sifted, to strain out the waxed ends and knots of thread that cause the provoking little lumps that catch our pen when we write rapidly on poor paper. 6th. It flows over an endless or circular belt of wire-gauze, about 30 feet long, beneath which is a steam air-pump that greedily sucks down the water from the pulp, as it slowly passes along, gaining consistency and firmness until it comes to a part of the belt called the “dandy-roll,” consisting of a cylinder, on the surface of which are wires arranged in parallel rows, or fancy letters, which print upon the moist paper any design—constituting what are termed “laid,” “wire-wove,” or “water-marks.” 7th. The paper, very soft and moist as yet, but still quite paperish in its appearance, passes between rollers that squeeze out the water; then between others which are hot and dry it, which bring it, 8th, to a vat of sizing, composed of the same material as the gelatin of calves-foot jelly, into which it plunges, and at the opposite side emerges only to come between other rollers that squeeze and dry it—at the end of which it passes under a cylinder, set with knives that clip the roll into sheets of any desired size.

PARCHMENT is prepared by plunging unsized paper for a few seconds in SO_3 and HO , then washing off the acid. This strengthens it in some unknown way, and entirely changes its appearance and character, so that a narrow strip will support a hundred-pounds weight, though before a small fraction of that would have torn it instantly.

LINEN.—This is made from the inner bark of flax. The plant is first *pulled* from the ground to preserve the entire length of the stalk; next “rotted” by exposure to air and moisture, when the decayed outer bark is removed by “breaking;” then, by “hatcheling,” the long fine fibres are divided into shreds, and laid parallel, while the tangled ones are separated as “tow.” It is then bleached on the grass, which renders the gray coloring-matter soluble by boiling in lye. The whitened flax is lastly woven into cloth.

COTTON consists of the beautiful hollow white hairs arranged around the seed of the cotton-plant. As it is always pure and white—except Nankin cotton, which is yellow—it would require no bleaching did it not become soiled in the process of spinning, etc.

GUN-COTTON is prepared by dipping cellular tissue—cotton, sawdust, printing-paper, etc.—in strong NO_5 . It is then carefully washed and dried. It is not materially changed in appearance, although it has less strength. It sometimes takes fire at the boiling-point of HO . It explodes with much greater violence and suddenness than gunpowder, and for that reason is more liable to burst the gun.

COLLODION is a solution of gun-cotton in sulphuric ether and alcohol. It forms a syrupy liquid, which is an excellent substitute for courtplaster.

EREMACAUISIS.—When wood decays slowly in the open air, the H passes off first, the proportion of C increases, the color darkens, and a black carbonaceous mass like muck remains, called humus. This is of great value to the soil, as its pores absorb NH_3 , and by its decay furnishes that and CO_2 to the growing plant. When the supply of humus is exhausted from the soil, we restore it by adding straw, etc., and by ploughing under green crops.

DESTRUCTIVE DISTILLATION OF WOOD.—When wood is heated to a high temperature, with no O present, or an imperfect supply, as in our stoves, it is decomposed, the charcoal remains, while the volatile constituents pass over in the form of illuminating gas, HO, pyroligneous acid, and wood-tar. The last is a thick liquid used for calking and tarring ships; on distillation it yields *benzole*, *creosote*, and *paraffine*.

PYROLIGNEOUS ACID (*wood-vinegar*) is obtained by the distillation of beech-wood. It contains much creosote and acetic acid. On account of the former substance, it is used for curing hams in commerce, and on account of the latter, for making salts called acetates.

CREOSOTE (flesh preserver) is a colorless liquid with a flavor of burnt wood. It is poisonous when taken in any quantity. It is a powerful antiseptic, and a mixture of 1 part creosote in 100 parts HO will, in a

few hours, give a ham a delicate smoky flavor and render it incapable of putrefaction. Creosote imparts to smoke its characteristic odor, and renders it so irritating to the eyes, and also gives to it the power of curing hams, dried beef, etc.

TAR is made, like charcoal, by burning heaps of wood under a covering of earth which excludes the air: an imperfect combustion ensues, the resinous matter exudes, and, trickling down to the hollow bottom, collects and runs into a reservoir. On the extensive pine-barrens of North Carolina the tar of commerce is principally produced.

TURPENTINE.—When tar is distilled it separates into pitch, which remains, and oil of turpentine, which passes off. The latter, redistilled, forms the rectified “spirits of turpentine.” The residuum of the distillation is called “rosin.”

COAL-TAR is formed, as we have seen, in the process of making illuminating gas. This was formerly thought valueless, but is now used for a variety of purposes. As a cement for roofs, walks, and pavements, for oiling machinery, and preserving wood from decay, it is invaluable. On distillation it yields the following, among other products: 1st, *benzole* (benzine), used as a solvent for gutta-percha, caoutchouc, wax, and for removing grease-spots. This, by distilling with NO_3 , gives *nitro-benzole*, which so nearly resembles the oil of bitter almonds that it is used for it in perfumery, confectionery, etc. By heating it with acetic acid and iron-filings

aniline is commonly prepared. 2d, *Paraffine*, a hard, white, tasteless solid, like spermaceti. It forms beautiful candles, which look and burn like the finest of wax. 3d, *Aniline*, from which some of the most exquisite colors of every shade are produced. Example: Mauve, magenta. When first prepared, aniline was worth more than gold, and is even now expensive; but its dyeing properties are very intense. (Who but a chemist would have searched for such brilliant colors in coal-tar!) 4th, *Carbolic acid*, which, by heating with NO_5 , dyes a rich yellow; it is also used as a disinfectant. The production of dye-stuffs from coal-tar formed an era in organic chemistry, and revolutionized the whole art of dyeing and calico-printing.

PETROLEUM is doubtless the product of the distillation of organic matter beneath the surface of the earth. It is not always connected with coal, as it is often found outside the coal-measures, as in Northwestern Pennsylvania and New York. The distillation must have taken place at a much greater depth than that at which the oil is now found, as it would naturally rise through the fissures of the rock and gather in the cavities above. Sometimes the oil has collected on the surface of subterranean pools of salt-water, so that after a time the oil is exhausted, and salt-water only is pumped up; or if the well strikes the lower part of the cavity, the water will first be pumped and afterward the oil. The crude oil from the well is purified by distillation. That

which passes over at the lowest temperature is called *naphtha*: as the heat is increased, there passes over next the *kerosene oil* for illumination, and lastly the *lubricating oil*. The kerosene is deodorized and decolorized by the use of sugar of lead, SO_2 , KO , and other chemicals, which are stirred in the oil, after which it is redistilled.

Bitumen or *Asphaltum*.—Petroleum (*petra*, a rock, and *oleum*, oil) and naphtha, flowing from the ground, have formed beds of bitumen in various parts of the world. This change is caused by a gradual oxydation and hardening, as turpentine changes to rosin. On the island of Trinidad is a lake called Tar Lake. It is nearly three miles in circumference. Below it is a bed of coal, from which the oil is doubtless distilled. The bitumen from the lake is used for the same purposes as pitch, which it closely resembles. Near the shore it is hard and compact, except in hot weather, when it becomes sticky. At the centre it is soft, and fresh bitumen boils up to the surface. Asphaltum is found in immense quantities in California and in Canada. It is a natural cement for laying stone or brick. It was used in building the walls of Babylon, for which purpose it was gathered from the fountain of Is on the banks of the Euphrates. It was a prominent ingredient in the "Greek Fire," so much used by the nations of Eastern Europe in their naval wars, even as late as the fourteenth century. This consisted of bitumen, sulphur, and pitch, which was

thrown through long copper tubes, from hideous figures erected on the prow of the vessel. It was said to be inextinguishable except by wine or vinegar. Bitumen is used in making the famous promenades of the Boulevards in Paris.

CANE-SUGAR ($C_{12}H_{11}O_{11}$)* is obtained from the sap of the sugar-maple, sugar-cane, sorghum, and the juice of the beet. In making it from the sugar-cane, the canes are crushed between iron cylinders, thus expressing the juice. As it sours very soon, from the heat of the climate in which it grows, a little lime is added to neutralize the acid, and it is then evaporated to a thick jelly, and set aside to cool. The sugar crystallizes readily, forming *brown sugar*, which is put in perforated casks to drain. The drainings constitute molasses.

Refining of Sugar.—Brown sugar is refined by dissolving it in HO, then adding albumen (whites of eggs, blood, etc.), which, on heating, coagulates and settles to the bottom with the coarser impurities. The solution is then filtered through animal charcoal,

* Ex.: A very brilliant illustration of the presence of C in $C_{12}H_{11}O_{11}$ is obtained by putting on a clean white plate a mixture of finely pulverized white sugar and $KO.ClO_3$. Upon adding a few drops of SO_3 , a vivid combustion will ensue. By mixing also a few iron and steel filings, and performing the experiment in a dark room, or out of doors at night, fiery rosettes will flash through a rose-colored flame, and produce a fine effect. The contrast between the white plate and mixture and the dense black carbonaceous compound covering the adjacent floor, is very striking to the eye.

and finally evaporated in vacuum-pans, from which the air is exhausted, so that the sugar boils at 140°F., and all danger of burning is avoided. From this the sugar crystallizes, and the white sugar is set aside to drain. The drainings constitute "syrup," "sugar-house molasses," etc.

ROCK CANDY is formed by suspending threads in a strong solution of sugar. It crystallizes upon the rough surface in large six-sided prisms.

CONFECTIONERY is commonly supposed to be made from sugar. Alba terra (white earth) is now largely imported from Ireland for use in lozenges, candy drops, etc., enough sugar only to flavor being added. We can and should test all the candy we purchase by putting a small piece in a glass of water. Whatever settles to the bottom cannot be sugar, but is a vile adulteration. Candies also are often colored by the direst poisons, so that prudence would forbid the use of any colored candy whatsoever. The grocer or dealer is as liable to be mistaken or ignorant in regard to the purity of his candies as we ourselves. Licorice drops are frequently only the poorest brown sugar, terra alba, and a flavoring of licorice to make the unwholesome mixture palatable. Gum-drops are generally made, not from gum-arabic, but the best kinds are composed of a species of glue manufactured out of hoofs, parings of hides, offal, etc., from the slaughter-houses. And yet, however repugnant it may appear, this glue is perfectly clean and wholesome. Many kinds of gum-drops and

lozenges are made from dextrine, terra alba, plaster of Paris, a little sugar, and some flavoring extract.

CAROMEL, familiarly called *burnt sugar*, is formed whenever sugar is heated above 400°F. , when it parts with four equivalents of water, leaving the C in excess, as when sweetmeats boil over on the stove. It is used extensively in coloring liquors.

GRAPE-SUGAR ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$).—This variety of sugar includes the sugar of grapes, figs, all common fruits, honey, etc., in which forms we are familiar with it. It has much less sweetness than cane-sugar.

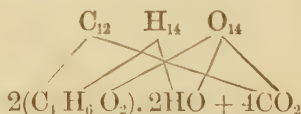
SUGAR FROM STARCH OR WOOD.—Starch and woody fibre differ only from grape-sugar by four atoms of HO. By slowly heating with SO_3 , diluted largely with HO, common sawdust, paper, and old rags even, can be converted into sugar. Indeed, Professor Pepper speaks of seeing some grape sugar that had been made in this manner out of an old shirt. The weight of sugar exceeds that of the woody fibre used by the additional four elements of HO. This change takes place in the plant. The green fruit contains starch, which, as the fruit ripens, is turned into grape-sugar. If it over-ripens, the sweetness is lost, as the sugar is reabsorbed by the plant and converted into woody fibre again. In the sap of the sugar-maple tree there is much grape-sugar, but as the leaves start they hasten to stop this pilfering of their sweet juices by turning it into cellular tissue—into the wood of the tree. The farmer knows that if he does not cut his grass at the

proper time it will undergo this change, and become tough and tasteless and of little value to him. The starch in potatoes is turned to sugar by freezing, and so frozen potatoes taste sweet.

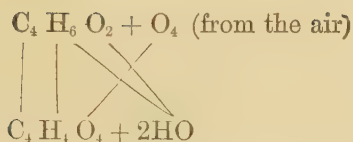
FERMENTATION.

If a solution of starch or sugar be exposed to the air it will undergo no change, but if there be added a little ferment or yeast, flour-paste, or any albuminous substance (*i. e.*, one containing N), in a decomposing state, it will immediately commence breaking up into new compounds. There are two stages in this chemical change.

1st. ALCOHOLIC FERMENTATION.—In this, *the sugar is resolved into alcohol, water, and carbonic acid*. The two former remain in the liquid, while the latter escapes in little bubbles of gas. The reaction is as follows:



2d. ACETOUS FERMENTATION.—The second stage succeeds the first immediately, if not checked, and by absorbing oxygen from the air, the *alcohol is broken up into acetic acid and water*.



YEAST is composed of microscopic plants formed during the process of fermentation. So minute are they, that it is said a cubic inch contains 1,200,000,000 of them. In the malting of barley they spring up in great abundance, making common brewer's yeast. The yeast-cakes of the kitchen are formed by exposing moistened Indian meal, containing a ferment, to a moderate temperature until the gluten or albuminous matter of the cake has undergone this alcoholic fermentation. It is then laid aside for use. A heat of 212° , or a cold of 10° , will kill the yeast plant and destroy its efficiency as a ferment.

MALT.—In making malt, the barley is thoroughly moistened, and then spread on the floor of a dark room (malting-room), to heat and sprout. Here a curious change ensues, identical with that which takes place in every planted seed. Each one contains starch and a nitrogenous substance called *gluten*. The tiny plant not being able to support itself in the beginning, has here a little patrimony to start with in life, but, as the starch is insoluble in its sap, it must first be changed to sugar. We see, therefore, the need of a ferment; but it would not answer to store up in the seed an active ferment, as that might cause a change before the plant was ready to

grow, and thus the plant's capital be wasted. The gluten is therefore a *latent* ferment, as it were. As soon as the seed is planted it absorbs moisture from the ground, is turned into *diastase*—an *active* ferment—the starch is converted into sugar, dissolved, and immediately applied to the uses of the growing plant. This change takes place in the *malting-room*. The barley sprouts, and a part of its starch is turned to sugar, so that it tastes quite sweet. If this germination were allowed to proceed, the little barley sprout would turn this sugar into woody fibre. To prevent this the grain is heated in a kiln until the germ is destroyed. Barley in this condition is called *malt*, and is then transported to the breweries.

BREWING BEER.—The malt is crushed and digested in water, to convert all the remaining starch into sugar. Having been boiled, to clarify it, hops and yeast are added, and fermentation immediately commences. Bubbles of gas rise to the top with a low hissing sound, yeast gathers into a foamy cream that comes to the surface of the tub, and the alcohol gradually accumulates in the liquid. It is now drawn off into tight casks, where it undergoes a second fermentation; the flavor of the beer ripens, and the CO_2 collecting, gives to the liquor, when drawn, its sparkling, foamy appearance.

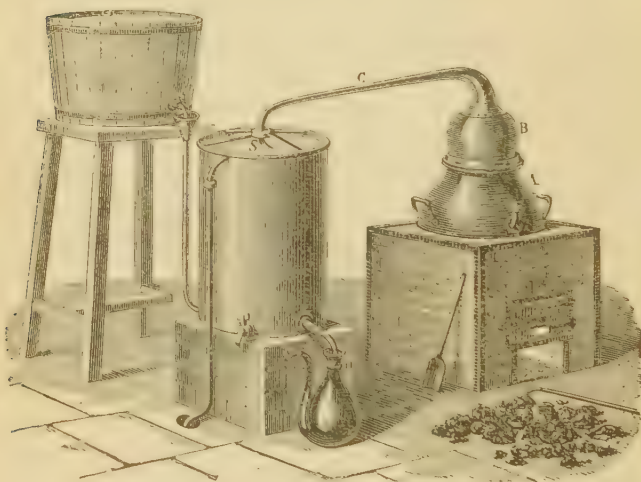
LAGER BEER (*Lagern*, to lie) is so called because it is allowed to lie for months in a cool cellar, where it ripens very gradually. It is also fermented much more slowly and perfectly than ale or porter.

WINES are commonly made from the juice of the grape. The juice, or *must*, as it is called, is placed in vats in the cellar, where the low temperature produces a very slow fermentation. Before the sugar is all converted into CO_2 and alcohol, the wine is bottled. The undecomposed sugar gives the flavor to sweet wines, while the CO_2 , formed afterward and dissolved in the liquid, produces the effervescence of sparkling wines. The sugar keeps the wine and rather improves its body for even a couple of centuries. The bouquet, or flavor of wines, is given by a very volatile liquid called *cenanthic ether*. It is developed in its perfection by age alone, and gives the value to old wines. The acidity of wine is due to a small quantity of tartaric acid combined with KO, forming the bitartrate of potash (cream of tartar), which gradually separates and collects upon the sides and bottoms of the casks and bottles in a white incrustation.

ALCOHOL IN BEER AND WINE.—Alcohol is the intoxicating principle alike of all varieties of liquors, ale, beer, wine, cider, and the domestic wines. Ale contains from five to ten per cent. of alcohol; wine varies from five per cent. in the light Champagne to twenty-five per cent. in the strong Port, Madeira, or Sherry.

ARDENT SPIRITS.—When any fermented liquor is distilled, the alcohol passes over at a temperature of 173° , together with some water and fragrant substances which are condensed. In this way

brandy is made from wine; rum from fermented molasses; whiskey from fermented corn, rye, or potatoes; gin from fermented barley and rye, afterward redistilled with juniper-berries; alcohol alone from whiskey. The percentage of alcohol in these spirituous liquors varies from fifty to seventy per cent. The accompanying cut represents an apparatus used for this distillation. A is the boiler, B the



A Still.

dome, C a tube passing into S, the condenser, where it is twisted into a spiral form called the worm, in which the vapor from the boiler is condensed, and drops out at D.

ALCOHOL (C_2H_6O) is prepared by distilling whiskey.

and is sometimes called spirits of wine. It boils at 173° , and has never been frozen even at -166° F. It contains, when purest, ten per cent. of HO, which can be separated by adding some substance like CaCl, which has a strong affinity for HO. It is then called *anhydrous* or absolute alcohol. When $C_4H_6O_2$ is exposed to the air the spirit evaporates, while it also attracts moisture from the atmosphere. The chemist discovers this when he neglects to put the extinguisher on his alcohol-lamp and finds that he cannot relight it without moistening the wick with fresh alcohol. It burns without smoke and with intense heat, owing to the abundance of H and deficiency of C, and is therefore of great value in the arts. It is also of incalculable importance as a solvent in forming tinctures of many substances—roots, resins, fragrant oils, etc.

Effects of Alcohol.—When pure it is a deadly poison. When diluted, as in the ordinary liquors, it is stimulative and intoxicating. Its influence is on the brain and nervous system;—deadening the natural affections, dulling the intellectual operations and moral instincts; seeming to pervert and destroy all that is pure and holy in man, while it robs him of his highest attribute—reason. It is a blight upon a family, a curse to society, and the bane of our civilization. In a word, alcohol makes drunkards, and a drunkard is the saddest, most shocking sight this world affords.

ETHER (C_4H_5O).—Sulphuric ether is formed by the

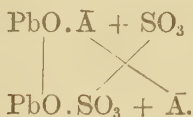
distillation of $C_4H_6O_2$ with SO_3 . The SO_3 simply takes an atom of HO out of the alcohol. It has a fragrant odor, boils at 96° , and burns with more light and smoke but less heat than alcohol. By the action of the other acids on $C_4H_6O_2$ varieties of ether are produced—viz., nitric ether, carbonic ether, etc.

AMYLIC ALCOHOL (*fusel oil*) is one of a large class of substances similar to alcohol, and thus called "the alcohols." It is formed in distilling whiskey from potatoes. It is present in common $C_4H_6O_2$, giving that slightly unpleasant odor when it evaporates from the hand. It is extremely poisonous, and though contained in liquors in very small quantities, is said to greatly increase their destructive and intoxicating properties. It is of interest, mainly because by distilling it with different acids, various products are obtained, having the most delicate flavor and odor. Pear, apple, orange, and many other "flavoring essences" are thus prepared. Though made from the poisonous fusel oil, they are perfectly innocuous.

CHLOROFORM (C_2HCl) is made by distilling $C_4H_6O_2$ with chloride of lime. It is colorless, volatile, of a sweet taste, and should be free from any unpleasant odor when evaporated on the hand. It is mainly used as an anæsthetic. The value of ether and chloroform in alleviating pain, is beyond estimate. On the battle-field, in hospitals, everywhere, our soldiers have sunk into pleasant slumber, while the

most painful surgical operations have been performed.

ACETIC ACID ($C_4H_4O_4:\bar{A}$).—When any fermenting substance has reached the first stage—the *alcoholic* fermentation—if the process be not stopped, it passes on to the second—the *acetous* fermentation, forming acetic acid and water. This acid is well known as common vinegar, of which it forms about five per cent. The acid of commerce is prepared by the action of SO_3 on acetate of lead (sugar of lead) $PbO.\bar{A}$. The reaction is—



CIDER VINEGAR.—Cider contains some nitrogenous matter, which acts as a ferment, and the starch of the apple is broken up into alcohol and carbonic acid. This makes what is called "*old cider*." By exposure to the air and heat, which always hastens chemical change, the alcohol passes on to the second stage, and the acetic acid formed produces the sour taste of the vinegar. "*Mother*," in vinegar, is a plant produced by the decomposition of the nitrogenous matter. It acts as a ferment, and frequently generates a nation of infusoria—vinegar eels. Acetic acid is a solvent of albumen, gelatin, fibrin, etc. Hence it takes from meat, eggs, oysters, etc., pickled in it, their most strengthening constituents. For the

same reason, vinegar is a valuable assistant in digesting such food. It allays thirst, and was anciently carried by the Roman soldiers in a little flask for that purpose. In the case of young ladies who use it (as well as slate-pencils), to relieve corpulency, it produces delicacy and finally consumption. Any sugar added to vinegar quickly passes to the second stage of fermentation, and increases its strength. Indeed, vinegar is sometimes made entirely from tea-leaves, which act as the ferment, and sweetened water. Vinegars of commerce are frequently sharpened by the addition of SO_3 and pungent spices. We can easily detect these by evaporating a half-gill in a saucer, placed over boiling water. As it boils down, add a little honey. If the grape-sugar it contains turns black, it is proof of the presence of SO_3 . As the last of the liquid evaporates, the odor of cayenne pepper, etc. (if there be any), can be readily distinguished.

A new Method.—The following method has lately been adopted in England. A thin liquid made from malt and HO is allowed to pass into the first stage of fermentation. A large vat is filled with short pieces of wicker-work, which are kept wet with an old vinegar wash until the surface of the wicker-work is covered with young vinegar-plants; these grow until they fill all the empty space. The weak alcoholic liquid is now permitted to trickle down through this vat full of *mother*, while at the same time the heat of the chemical change causes an upward cur-

rent of air through holes at the bottom of the vat. Before the liquid reaches the faucet below, it passes into the second stage of fermentation.

QUICK VINEGAR PROCESS.—Vinegar is now made on a large scale by filtering a mixture of alcohol and yeast through a cask filled with beech shavings soaked in vinegar. As the fermenting alcohol slowly trickles down, it comes in close contact with the air, absorbing O so rapidly that sometimes before it reaches the bottom it becomes entirely converted into vinegar.



PRESERVES frequently *work*, as it is called, and then *sour*. The bubbles of gas which rise to the surface indicate the first or alcoholic stage of fermentation. If neglected, this soon passes to the second. It may be checked by scalding, which destroys the ferment.

VEGETABLE ACIDS.

There are many of these found native in plants—most generally, however, combined with some base.

OXALIC ACID ($C_4H_6:O$) is familiar in the sour taste of pie-plant, sorrel, etc., in which it is combined with KO, which largely neutralizes its acid properties. It is prepared by the action of NO_5 on sugar.* $\bar{O}$

* Oxalic acid is also made on a large scale from sawdust, soda, and potash. The woody fibre is resolved into oxalic acid,

is a potent poison. Its antidote is a drink of powdered magnesia, or chalk, stirred in HO. It is a test of lime, forming a delicate white precipitate of oxalate of lime. Its solution is much used to remove ink stains, and it is sold for this purpose under the deceptive and dangerous name of "salts of lemon." The acid unites with the iron of the ink, and the oxalate of iron thus made is easily dissolved in HO. It should be thus washed out immediately, as it will corrode the cloth. The crystals of $\bar{O}$, it should be noticed, very much resemble those of Epsom salts, and many serious mistakes have occurred in consequence.

TARTARIC ACID ($C_4H_4O_6 : \bar{T}$) exists in many fruits, principally in the grape, combined with KO as $KO.2\bar{T}$, the bitartrate of potassa. This settles during the making of wine, as we have seen, and when purified is called *cream of tartar*. From this $\bar{T}$ is made. It forms large, colorless crystals, of a pleasant acid taste, which are permanent in the air. Its solution gradually becomes mouldy and turns into $\bar{A}$. *Rochelle salt* is a double tartrate of potassa and soda; it is a purgative, and is much used in Rochelle, or *Seidlitz*, powders. These are combined in a blue and a white paper. The former holds 120 grains of Rochelle salt, and 40 grains of bicarbonate of soda;

which combines with the bases, forming oxalates of soda and potash. From these the acid is readily obtained. Sawdust will yield more than half its weight of crystals of this salt.

the latter 35 grains of tartaric acid. These are dissolved in separate goblets. The one containing the acid is emptied into the other, when the CO_2 is set free, producing a violent effervescence and disguising the taste of the medicine. *Tartar emetic* is a double tartrate of potassa and antimony.

CITRIC ACID (*citrus*, lemon) is the sour principle of the citron, orange, lemon, cranberry, etc. It is combined with lime in the onion.

MALIC ACID (*malus*, an apple) is found in the apple, peach, pear, plum, cherry, etc.

TANNIC ACID (*tannin*) is found in the leaves and bark of many trees. Example: Oak, hemlock, sumach. Nutgalls are excrescences which form on oak-trees when punctured by insects for the purpose of laying their eggs. Tea and coffee contain from 8 to 10 per cent. of tannin. It has a bitter, astringent, puckering taste, is soluble in water, and hardens all albuminous substances, such as gelatine, etc.

TANNING.—After the hair has been removed from the skins by milk of lime, they are soaked for days, the best kinds for months, in vats full of water and ground oak or hemlock bark (tan-bark). The tannic acid of the bark is dissolved, and entering the pores of the skin, unites with the gelatin, forming a hard insoluble compound which is the basis of leather. Leather is blackened by washing the hide on one side with a solution of copperas ($\text{FeO}.\text{SO}_3$). The tannic acid unites with the iron, forming a tannate

of iron—a real ink. In the same way drops of tea on a knife-blade stain it black.

INK is made by adding a solution of nutgalls to one of copperas. The tannate of iron thus formed has a pale blue-black color, as in the best writing-inks. By exposure to the air the iron absorbs more O , and becomes changed from the protoxide to the sesquioxide, thus darkening in color until it is a deep black. Gum-arabic is added to the ink to thicken it and regulate its flow from the pen. Cloves or corrosive sublimate are used to prevent mouldiness. Steel pens are corroded by the free SO_3 contained in the ink, but gold pens are not affected by it.

Experiment.—The following is an instructive experiment, illustrating the manner of making ink, of removing stains with oxalic acid, and also the relative strength of the acids and alkalies. Take a large test-tube, and add the following reagents in solution *cautiously, drop by drop*, watching the result and explaining the reactions :

Sulphate of iron (<i>copperas</i>)	$FeO \cdot SO_3$
Tannic acid (<i>tannin</i>).....	$C_{54} H_{22} O_{34}$
Oxalic acid	$C_4 H_4$
Carbonate of soda (<i>sal-soda</i>)	$NaO \cdot CO_2$
Hydrochloric acid (<i>muriatic</i>).....	HCl
Ammonia (<i>hartshorn</i>)	NH_3
Nitric acid (<i>aqua fortis</i>)	NO_5
Potassa (<i>potash</i>)	KO
Sulphuric acid (<i>oil of vitriol</i>)	SO_3

GALLIC ACID is always a companion of tannin in

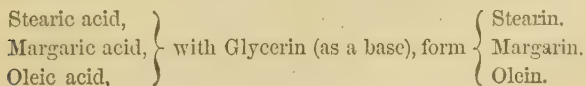
the substances we have named, and is formed from it by exposure to the air. In some hair-dyes the hair is first wet with gallic acid, and then with a solution of nitrate of silver. The acid decomposes the salt, and the liberated oxyd of silver colors the hair.

OILS AND FATS.

The difference between oils and fats is only that of temperature; the former remain liquid at ordinary degrees of heat, while the latter is a solid. "A fat may be called a solid oil, and an oil a liquid fat," with equal propriety. The peculiar odor of each is due to some volatile acid. They are divided into two classes—fixed oils and volatile oils. The former produce a permanent stain on paper, the latter do not. "A cork twisted into the neck of a bottle containing a fixed oil makes no noise; in a volatile oil it squeaks.'

THE FIXED OILS.

Constitution.—All fatty bodies are salts, being composed of *stearin*, *margarin*, and *olein*. These consist of three acids—stearic, margaric, and oleic, combined with a common base, glycerin; thus:



The first two of these salts are solids at common temperatures, and form fats; the latter is a liquid, and forms oils. The relative proportion of olein contained in any fatty substance determines its fluidity. Ex.: Stearin is abundant in tallow, and margarin in butter, hence their comparative consistency. Lard, on the other hand, contains so much olein that it is expressed in large quantities as "lard-oil." Olive-oil contains much olein and margarin; the former remains fluid at ordinary temperatures, but the latter, in cold weather, hardens into a thick deposit, and renders the oil extremely viscid.

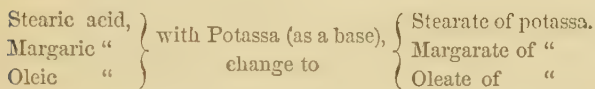
GLYCERIN is named from its sweet taste. It is made from tallow, and is an odorless transparent syrup. It is soluble in HO and alcohol. Its healing properties are remarkable, and its use is common in dressing sores, insect bites, chapped hands, etc. When highly heated it is decomposed, and produces an acrid substance (acroleine) with which we are familiar in the disagreeable smell of a smouldering candle-wick and burning fat.

By the action of NO_3 and SO_3 glycerin is converted into *nitro-glycerin*, an oil that explodes with most fearful violence by the slightest concussion, or even from unexplainable causes. It is used in blasting.

LYE is a strong solution of KO, and is obtained, as we have seen, by leaching ashes. The alkali is contained in the ashes in the form of KO.CO_2 . At the bottom of the leach-tub a little lime is commonly

placed to absorb the CO_2 and leave the KO unneutralized by the acid, and therefore stronger.

HOME-MADE SOAPS are formed by heating "lye" and "soap-grease." In this process the potassa of the lye drives off the glycerin of the grease and makes new salts which contain KO, instead of glycerin, as the base; thus:



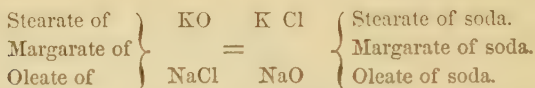
These three salts constitute soap. The expelled glycerin remains floating around alone through the mass. This soap is soft because of the attraction of KO for HO. The boiling merely hastens the chemical change. It takes place more slowly in the making of "cold soap."

HARD SOAP contains soda instead of KO as a base. This is not deliquescent,* and so the soap retains its solid form. Soda soap can be formed from potassa soap by the addition of common salt (NaCl).

Reaction.—The O of the potassa (KO) unites with the sodium (Na) of the salt (NaCl), forming soda (NaO). The chlorine (Cl) of the salt (NaCl) unites with the potassium (K) of the potassa (KO), forming chloride of potassium (KCl). The soda thus formed displaces the potassa, and makes a hard or soda

* A deliquescent body is one that dissolves in HO, which it absorbs from the air.

soap, while the KCl remains dissolved in the water; thus :

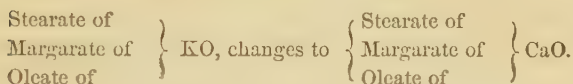


The kind of fat used, by the amount of olein it contains, also determines the softness of the soap. Ex. : Tallow makes a harder soap than lard, since it has less olein. Soap has a powerful affinity for HO, and will readily absorb 50 per cent. of its weight. It is therefore noticeable that dealers commonly keep their soaps in cellars or damp places. The best old soap contains at least 20 per cent.

FANCY SOAPS.—Castile soap is composed of olive-oil and soda. Its mottled appearance is caused by oxyd of iron, which is stirred through it in fanciful designs while it is yet soft. Yellow soaps contain rosin in part, instead of fat, forming a rosin soap. *Cocunut-oil* makes a soap which will dissolve in salt water, and is therefore used at sea. It also forms a strong lather, and is sold as “shaving-soap.” *Washing fluids* contain an unusual amount of alkali, and are therefore apt to be injurious to the cloth. *Soap-balls* are made by dissolving soap in a very little water, and then working it with starch to a proper consisteney to be shaped into balls. White toilet-soaps are made from lard and soda.

SOAP IN HARD WATER.—Water containing any mineral matter will not dissolve soap, since the lime,

magnesia, etc., displace the alkali in the soap, and form a new soap which is not soluble, but floats on top as a greasy scum. Example: A potassa soap in lime-water changes to a lime soap. Thus—



THE CLEANSING QUALITIES OF SOAP.—There exudes constantly from the pores of our skin an oily perspiration, and this, catching the floating dust, dries into a film of greasy dirt which will not dissolve in water. The alkali of soap combines with this oily substance and makes a soap of it, which is soluble. In addition to this the alkali also dissolves the cuticle of our skin, and thus produces the “soapy feeling,” as we term it, when we handle soap.

SOAPSUDS consist of a thin film of soap filled with bubbles of air. They are an excellent remedy in almost all cases of poisoning, and where the exact antidote is not at hand should be taken immediately. Soap-bubbles are said to be only two-millionths of an inch in thickness.—(*Newton.*) They are thinnest at the top, as the water runs down the sides toward the bottom constantly. These falling films of water cause the refraction of light, and a beautiful play of colors.

ADULTERATION.—Soap is frequently contaminated

with gypsum, lime, pipe-clay, etc. These may be detected by dissolving a small piece in alcohol and noticing if there be any precipitate.

CANDLES are made from tallow, stearin, paraffine, wax, spermaceti, etc. Tallow candles and their manufacture are too well known to need description. *Stearin* or *adamantine* candles are moulded like ordinary candles. They are prepared from tallow or lard, which is first boiled with lime and so made into a soap. This soap is decomposed by sulphuric acid, which takes away the lime, forming sulphate of lime, which, being insoluble, sinks to the bottom, leaving the three acids of the fat floating upon the surface. The glycerin is also left by itself in the liquid, from whence it is removed and prepared for the market. The acids, when cool, are subjected to great pressure; the olein flows out, leaving the stearic and margaric acids as a milk-white, odorless, tasteless solid, which is commonly called stearin, since that acid is the principal constituent. *Paraffine candles* are made from coal-oil, as we have already described. *Wax candles* are manufactured by the following process. A large number of cotton wicks are hung upon a revolving frame with projecting arms. The wicks are fitted at the end with metal tags to keep the wax from covering that part. As the machine slowly turns, a man, standing ready with a vessel of melted wax, carefully pours a little down each wick in succession. This process continues until the candles are fed to the desired size.

They are then well rolled on a smooth stone slab, the tops cut by conical tubes, the bottoms trimmed, and they are ready for use. The large tapers burned in Catholic cathedrals are made by placing the wick on a sheet of wax, rolling it up till the right thickness is reached, when the candle is trimmed and polished as before.

Spermaceti candles are run from the white crystalline solid fat which is found with sperm oil in the head of the sperm whale.

WAX is found in nearly all plants. It forms the shiny coating of the leaves and fruit. Example: Lemon leaf, apple. Certain plants in Japan contain so much wax that it is separated by boiling and used for making candles. Bees gather the wax for the construction of their comb partly from flowers, and a part they manufacture from the sweet juices sipped from the flowers. Yellow beeswax is bleached by exposure in thin ribbons to the air.

LINSEED OIL is a *drying oil*, as it is termed—*i. e.*, it absorbs O from the air, and hardens by exposure. It is expressed from flaxseed, which furnishes about one-fifth of its own weight of oil. *Boiled oil* is made by boiling the crude oil with litharge (PbO) for several hours. The oxyd of lead combines with the gummy mucilage of the oil, which collects as a slimy sediment. Linseed oil is used in mixing paints and varnishes. Putty consists of linseed oil and chalk (*Whiting*) well mixed. Printers' ink is made by burning linseed oil until it becomes thick and viscid,

when lampblack is stirred in, to make it of the proper consistency.

COD LIVER OIL is extracted from the liver of the codfish. It contains I, Br, and P, and is much used as a remedy in Consumption.

CROTON OIL is made from the seeds of an Indian plant; and is used as a powerful purgative and for causing eruptions on the skin.

CASTOR OIL is extracted from the castor-oil bean. It is used as a purgative, and also in perfumery and hair-oils.

SWEET-OIL, OR OLIVE-OIL, is an *unctuous oil*, i. e., it absorbs O on exposure to the air—not hardening like the drying oils, but remaining sticky, and after a time becoming rancid from the formation of disagreeable volatile acids. Sweet-oil is expressed from the olive fruit. In Europe it is extensively used instead of butter. It is employed as a machine-oil, although the coal-oils are now much preferred.

VOLATILE OILS.

The Volatile oils, unlike the Fixed, make no soaps, and dissolve readily in alcohol or ether. Their solution in alcohol forms an essence, hence the term “essential,” by which they are frequently called.

Source.—They are principally of vegetable origin. They are found in the petals of a flower, as the violet; in the seed, as caraway; in the leaves, as mint; in the root, as sassafras; and sometimes

several kinds of oil are obtained from different parts of the same plant. Example: The flower, leaves, and rind of the orange-tree furnish each its own variety. The perfume of flowers is produced by these volatile oils; but how slight a quantity is present may be inferred from the fact that one hundred pounds of fresh roses will give scarcely a quarter of an ounce of Attar of Roses.

Preparation.—In the peppermint, the wintergreen, and many others the plant is distilled with water. The oils pass over with the steam, and are condensed in a refrigerator connected with the “Mint Still.” The oil floats on the surface of the condensed water, and may be removed. A small portion, however, remains mingled with the latter, which thus acquires its peculiar taste and odor, constituting what is termed a “perfumed water.” Example: Rose-water, peppermint-water. In some flowers, as the violet, jasmin, etc., the perfume is too delicate to be collected in this manner. They are therefore laid between woollen cloths saturated with some fixed oil. This absorbs the essential oil, which is then dissolved by alcohol. Oil of lemon is obtained from the rind of the fruit by expression or by digesting in alcohol. Example: A good essence is made by putting bits of lemon-peel in a bottle of alcohol.

COMPOSITION.— C_5H_4 is the common symbol of a large number of these oils. Thus the oils of lemon, juniper, citron, black pepper, copaiba, bergamot,

turpentine, cubebs, and oranges, are isomeric. A second class contains, besides C and H, a little O; a third, in addition, has S.

FIRST CLASS OF VOLATILE OILS.—Turpentine is a type of this division. It is made by distilling pitch with HO. It is generally called *spirits of turpentine*. It is highly inflammable, and, owing to the excess of C, burns with a great smoke. By the union of an atom of its H with an atom of the O of the air to form HO, it is converted into rosin. In this way, when exposed in bottles half full, the turpentine around the nozzle becomes first sticky and then resinous. Old oil should not be taken to remove grease spots, as, while it will remove one, it will leave another of its own. *Camphene* is turpentine purified by repeated distillation. *Burning-fluid* is a mixture of camphene and alcohol. In the heat of the burning H of the latter, the C of the former is consumed, and this produces a bright light. The tendency of camphene to smoke is thus diminished, and the illuminating power increased. By the action of HCl on turpentine or oil of lemons an artificial camphor is produced very nearly resembling our common camphor.

THE SECOND CLASS includes the oils of bitter almonds, cinnamon, peppermint, roses, lavender, etc. They are sometimes called “The Camphors,” because of their general resemblance to the crystalline essence known by that name. Camphor ($C_5H_4O_2$) is obtained by distilling the roots and leaves of the camphor-

tree of Japan in water, and condensing the vapors in rice-straw. It is purified by sublimation. When kept in a bottle, it vaporizes, and its delicate crystals collect on the side toward the light. Taken internally, except in small doses, it is a virulent poison. Its solution in alcohol is called spirits of camphor. If HO be added to this, the camphor will be precipitated as a flour-like powder.

THE THIRD CLASS contains S, and sometimes N. It includes garlic, assafoetida, hops, onions, mustard, horseradish, etc. They are known for their pungent taste and the disagreeable odor they often impart to the breath. The oil of mustard is not contained in the seed, but is formed in it by the action of water and a latent ferment. This is the reason why mustard, when first prepared for the table, is bitter, but becomes pungent after a little time.

RESINS AND BALSAMS.

Resins are formed from the essential oils by oxydation. Example: *Turpentine*, as we have just seen, is changed to rosin, a resinous substance. If the resin is dissolved in some essential oil it is called a balsam. Example: *Pitch* is a true balsam, since by distillation it is separated into rosin and turpentine.

Source.—They mostly exude from incisions in trees and shrubs, in the form of a balsam, which oxydizes on exposure to the air, and becomes a resin. Example: Common plum-tree, pine-tree.

Properties of Resins.—They are translucent, brittle, insoluble in HO, but soluble in ether, alcohol, or any volatile oil, are non-conductors of electricity, and burn with much smoke. They do not decay, and, indeed, have the power of preserving other substances. For this reason they were used in embalming the bodies of the ancient Egyptians, which, after the lapse of two thousand years, are yet found dried into mummies in their mammoth tombs—the Pyramids.

ROSIN constitutes about 75 per cent of pitch. It is used in making soaps, to increase friction in violin bows and the cords of clock-weights, in soldering, and as a source of illuminating gas. Shoemakers' wax is made by burning rosin until partly charred.

LAC exudes from the ficus-tree of the East Indies. An insect punctures the bark, and the juice flows out over the insect, which works it into cells in which to deposit its eggs. The dried gum incrusting the twigs is called *stick-lac*, when removed from the wood it is *seed-lac*, when melted and strained, *shellac*. The liquefied resin is dropped upon large leaves, and so cools in broad thin pieces, as we buy it. *Sealing-wax* is made of shellac and turpentine; vermilion is added to give the red color. Shellac is much used in making varnishes.

GUM BENZOIN also exudes from a tree in the East Indies. It contains benzoic acid. It is used in fumigation, in cosmetics, and on account of its fragrant odor is burnt as incense. Ex.: Place some green sprigs under a glass receiver, and at the bottom a hot iron, on which sprinkle a little benzoic acid. It will sublime and collect in beautifully delicate crystals on the green leaves above, making a perfect illustration of winter frost-work.

AMBER is a fossil resin which has exuded in some past age of the world's history from trees now extinct. It is sometimes found containing various insects perfectly preserved, which were without doubt entangled in the mass while it was yet soft. These are so beautifully embalmed in this transparent glass that they give us a good idea of the insect life of that age. It is cast up by the sea, in pieces of a few ounces each, on the shores of the Baltic and off the coast of New Jersey. It is commonly translucent, and susceptible of a high polish. It is used for ornaments, mouth-pieces, necklaces, buttons, etc. It is a prominent ingredient in carriage varnish.

CAOUTCHOUC or INDIA-RUBBER is a pure hydrocarbon, and may be considered as hardened illuminating gas. It exudes from certain trees in South America as a milky juice. The globules of rubber are suspended in it as butter is in milk. By adding ammonia the sap may be kept unchanged for months, and is sometimes exported in that form preserved in tightly corked bottles. The tree, it is said, yields

about a gill per day from each incision made. A little clay cup is placed underneath, from which the juice is collected and poured over clay or wooden patterns in successive layers as it dries. To hasten the process it is carried on over large open fires, the smoke of which gives to the rubber its black color; when pure it is almost white. When nearly hard the rubber will receive any fanciful design which may be marked upon it with a pointed stick. The natives often form the clay into odd shapes as bottles, images, etc., and the rubber is sometimes exported in these uncouth forms. The solvents of rubber are ether, naphtha, coal-oil, turpentine, benzole, etc. It melts, but does not become solid on cooling. It loses its elastic power when stretched for a long time, but recovers it on being heated. In the manufacture of rubber goods for suspenders, etc., the rubber thread is drawn over bobbins and left for some days until it becomes inelastic. In this state it is woven, after which a hot wheel is rolled over the cloth to restore the elasticity.

VULCANIZED RUBBER is made by heating caoutchouc with a small amount of sulphur. This constituted Goodyear's original patent, and was discovered accidentally. While engaged in experimenting upon improvements in this branch of manufacture, he was one day talking with a friend and happened to drop a bit of sulphur in a pot of melted rubber. By one of those happy intuitions which seem to come only to men of genius, he watched the

result, and discovered—"Vulcanized Rubber!" It is less liable to be hardened by cold or softened by heat, and admits of many uses to which common rubber would be entirely unsuited. When, in addition, it is mixed with pitch and magnesia, it becomes a hard brittle solid, capable of a high polish, and is used for knife-handles, combs, and brushes.

GUTTA-PERCHA resembles caoutchouc in its source, preparation, and appearance. It softens in warm water, and can then be moulded into any desired shape. When cooled it assumes its original solidity. It is extensively used in taking impressions of medals, etc.

ORGANIC BASES.

The organic bases, or alkaloids, as they are called, are the bases of true salts found in plants. They dissolve slightly in HO, but freely in alcohol. They have a bitter taste, and rank among the most fearful poisons known. The antidote is tannin, which forms with them insoluble tannates. Any liquid containing it is of value—as strong green tea—and should be immediately administered in a case of poisoning by any of the alkaloids.

OPIMUM is the dried juice of the poppy plant, which is extensively cultivated in Turkey for the sake of this product. Workmen pass along the rows soon after

the flowers have fallen off, cutting slightly each capsule. From this incision a milky juice exudes and collects into a little tear. In twenty-four hours these are gathered and beaten up in an earthen jar with saliva to the proper consistency, when the mass is wrapped in leaves for the market. It is afterward purified. *

Properties.—Opium produces a powerful influence on the nervous system. It stimulates the brain and excites the imagination to a wonderful pitch of intensity. The dreams of the opium-eater are said to be vivid and fantastic beyond description.* The dose must be gradually increased to repeat the effect, and the result is most disastrous. The nervous system becomes deranged, and no relief can be secured save by a fresh resort to this baneful drug. Labor becomes irksome, ordinary food distasteful, and racking pains torment the whole body. No person can be too careful in the use of a narcotic whose influence is liable to become so destructive.

OPIMUM-SMOKING.—In China the custom of smoking opium is fearfully prevalent. The opium is made into a thick syrup with water. A small portion is placed in the bowl of the pipe, which is held in the flame of an oil-lamp until the opium is partly volatilized and fully ignited. During this process, the smoker, reclining upon his side, gently inhales the fumes, and absorbs them by retaining them until they slowly pass out through the nose. Opium-shops

* See APPENDIX.

are said to be more numerous in China than even rice-shops. The effect is worse than that of intoxicating liquors, if it is possible to compare two such fearfully pernicious vices.

MORPHIA.—*Morphine* is one of the alkaloid bases of opium. It is so called from Morpheus, the god of sleep. It is a bitter, narcotic, resinous-like substance. It is used principally as a sulphate of morphia, in doses of one-eighth to one-fourth of a grain, to alleviate pain and produce sleep. *Laudanum* is the tincture of opium. *Paregoric* is a camphorated tincture of opium, with benzoic acid and oil of anise.

QUINIA.—*Quinine* is prepared from Peruvian bark. It is employed in medicine as a tincture of Peruvian bark, or in the form of sulphate of quinia, for cases of fever and ague and all periodic diseases.

NICOTINE is the active principle of the tobacco plant. It is volatile, and passes off in the smoke. A drop will kill a large dog. It probably produces the ill effects that follow the use of tobacco.

STRYCHNIA.—*Strichnine* is prepared from the nuxvomica bean, obtained from a small tree in the East Indies. The "woorara," with which the South American Indians poison their arrows, is a variety of strychnine. This is so deadly that the scratch of a needle dipped in it would produce death. Strychnine is scarcely soluble in water, but freely in the essential oils and chloroform. It is so intensely bitter that one grain will impart a flavor to twenty-

five gallons of water. One-thirtieth of a grain has killed a dog in thirty seconds, while half a grain is fatal to a man.

The *Chromatic Test* consists in placing on a clean porcelain plate a drop of the suspected liquid, a drop of SO_3 , and a crystal of bichromate of potassa. Mix the three very slowly with a clean glass rod. If there be any strychnine present, it will change the color into a beautiful violet tint, passing into a pale rose. It is, however, one of the most difficult poisons to detect. Arsenic was formerly used by the poisoner, but Marsh's test infallibly reveals its presence in the body of the victim, even after many years have elapsed. But the organic poisons are so easily acted upon by the fluids of the system, that in one case, though four grains were taken, and death ensued very quickly, yet the "chromatic test" failed to reveal the presence of any strychnine in the stomach. However, the murderer is not to escape. This is the only poison except brucite (and that also is extracted from nux vomica) that produces tetanus or lock-jaw. This symptom infallibly proves to the physician that death has been caused by strychnine. To prove this conclusively, a tiny frog is brought into the court-room and made to show the effects of the poison. So sensitive is this little animal, that a few drops of oil containing only $\frac{1}{100,000}$ of a grain will instantly throw it into the most rigid locked-jaw, in which it is incapable of the least motion.

COFFEINE AND THEINE constitute the active prin-

riple of tea and coffee, and are isomeric. They crystallize in beautiful white prisms of a silky lustre. In addition, tea contains from 12 to 18 per cent. of tannic acid, some 15 per cent. of gluten, which is lost in the "grounds" (unless we imitate the Japanese and eat them with the tea), and a volatile oil which gives to it its peculiar aromatic odor and taste. Coffee contains 14 per cent. of a fixed oil, and also an essential oil which is developed in roasting, and is remarkably volatile, so that it soon escapes unless the coffee is kept tightly covered.

Tea-raising.—The tea-plants are allowed to grow only about a foot and a half high, and resemble in some respects the low whortleberry bush. They are grown in rows, three to five in a hill, very much as corn is with us. The medium-sized leaves are picked by hand, the largest ones being left on the bushes to favor their growth. Each little hill or clump will furnish from three to five ounces of green leaves, or about one ounce of tea in the course of the season. The leaves are first wilted in the sun, then trodden in baskets by barefooted men to break the stems, next rolled by the hands into a spiral shape, then left in a heap to heat again, and finally dried for the market. This constitutes BLACK TEA, and the color would be produced in any leaves left thus to wilt and heat in heaps in the open air. The Chinese always drink this kind of tea. They use no milk or sugar, and prepare it, not by steeping, but by pouring hot water on the tea and allowing it to stand for

a few minutes. Whenever a friend calls on a Chinaman, common politeness requires that a cup of tea be immediately offered him.

Green Tea is prepared like black, except that it is not allowed to wilt or heat, and is quickly dried over a fire. It is also very frequently, if not always, colored, cheap black teas and leaves of other plants being added in large quantities. In this country, damaged teas and the "grounds" left at hotels are re-rolled, highly colored, packed in old tea-chests, and sent out as new teas. Certain varieties of black tea even receive a coating of black-lead to make them shiny.

There are various other alkaloids that are worthy of mention merely. Lettuce contains one similar to opium, which gives it a slight narcotic influence. Aconite is obtained from monk's-hood, veratrine from the hellebore, solanine from the henbane, piperine from white, black, and long peppers—isomeric in white needle-shaped crystals.

ORGANIC COLORING PRINCIPLES.

With the exception of cochineal, all the organic coloring principles are of vegetable origin. The beautiful tints of flowers are so evanescent that they cannot be retained. Coloring matters are therefore taken of soberer hue from the interior of plants, where they are less exposed to the light.

DYEING.—Very few of the colors have such an

affinity for the fibres of the cloth that they will not wash out. Such as, like indigo, will dye directly are called *substantive* colors. But the majority require a third substance which has an attraction for both the coloring matter and the cloth, and will hold them together. Such substances are called *mordants* (from *mordeo*, to bite), because they bite the color into the cloth. The most common mordants are alum, oxyd of tin, and copperas. In dyeing, the cloth is first dipped in a solution of the mordant, and then of the dye-stuff. Ex.: If a piece of cotton cloth be dipped in a decoction of madder, it will receive an unstable dirty red color. If, however, it be soaked first in a solution of alum and sugar of lead ($\text{PbO} \cdot \bar{\text{A}}$), the acetate of alumina will be formed in its fibres, and will act as a mordant. Now dip it into the same dye, and it will come out a brilliant red—a “fast color.” The mordant, by means of a stamp, may be applied to the cloth in the form of a pattern, and when it is afterward washed, the color will all be removed except where the mordant fixed it in the printed figure. The same dye will produce different colors by a change of mordants. Ex.: Logwood and copperas will dye black; logwood and tin, a violet. Madder will dye in this way red, purple, yellow, orange, and brown. This principle lies at the basis of dyeing “prints.”

CALICO-PRINTING.—A calico-printing machine is very complex. The cloth passes between a series of rollers, upon which the corresponding mordant is

put, as ink is on type. A single machine sometimes prints from twenty sets of rollers; yet each impression follows the other so accurately, that when the cloth has passed through, the entire pattern is printed upon it with the different mordants more perfectly than any painter could do it, and so rapidly that a mile of cloth has been printed with four mordants in an hour. The cloth when it leaves the printing machine, though stamped with the mordants in the form of the figure, betrays nothing of the real design until after being dipped in the dye, which acting on the different mordants brings out the desired colors. The print is now washed, glazed, and fitted for the market.

RED AND VIOLET COLORING SUBSTANCES. — *Madder* is the root of a plant found in the East Indies. When first dug it is yellow, but by exposure to the air it absorbs O and becomes red. It is used in dyeing the brilliant Turkey-red. *Cochineal* is an insect that preys upon a species of cactus in Central America. It is raised in large plantations, dried between hot iron plates, and exported as an article of commerce. It yields the brightest scarlet and purple dyes. The *purple* of which we read in ancient writings was a secret with the Tyrians. King Hiram, we learn, sent a workman to Solomon skilled in this art. The dye was obtained from a shell-fish that was found on the coast of Phœnicia. Each animal yielded a tiny drop of the precious liquid. A yard of cloth dipped twice in this costly dye was worth \$150.

Brazil-wood furnishes a *red* which is not very permanent. It is used for making red ink. Experiment: Boil 2 oz. of Brazil-wood in a pint of HO for fifteen minutes, then add a little gum-arabic and alum.

BLUE COLORING SUBSTANCES.—The *indigo* of commerce is obtained from a bushy plant found in Asia. The juice is colorless, but by fermentation for some days, in vats of water, a yellow substance is formed, which by exposure to the air absorbs O, and changes to a deep blue. By any oxydizing agent the color of indigo may be removed at pleasure. Example: Add to a test-tube of boiling HO, colored with a solution of indigo,* a drop of NO₅. The blue color will instantly disappear. *Litmus* is obtained from certain kinds of lichens, which grow on the rocks along the coasts of France and England. The juice is colorless, like the other dye-plants, but assumes a rich purple blue by the addition of ammonia (NH₃).

GREEN COLORING SUBSTANCE.—Leaf-green, as found in plants, is a waxy substance, containing several coloring matters. It seems to lie in the cells of the leaf in minute crystals, and to be formed by the action of the sunbeam. Plants removed from a dark cellar to the open air grow green rapidly.

* To make this solution, mix a little pulverized indigo into a paste with SO₃. Let it stand a few days, then add HO at pleasure.

ALBUMINOUS BODIES.

The Albuminous bodies differ essentially from any yet named. They are far more complex in their structure, contain more nitrogen, and do not crystallize. The most important are—

Albumen,
Fibrin,
Casein.

These are physiologically isomeric, *i. e.*, they are all changed into albumen before leaving the stomach. When decomposed by an alkali they yield a white inodorous solid, which will act as a base and form salts. This is called "Protein" (*proteo*, I am first), and these substances themselves are termed the *protein compounds*. Their composition is very complex, as may be seen from the following table given by Liebig:

Albumen of blood.....	}	$C_{216}H_{169}O_{68}N_{27}S_2.$
Albumen of flesh.....		
Fibrin of flesh.....		
Albumen of eggs.....		$C_{216}H_{169}O_{68}N_{27}S_2.$
Casein.....		$C_{288}H_{226}O_{90}N_{36}S_2.$
Fibrin of blood.....		$C_{296}H_{226}O_{92}N_{40}S_2.$

ALBUMEN.—*Sources*.—It exists nearly pure in the whites of eggs*—hence the name (*albus*, white); also in the serum—the transparent part of the blood—and the juices and seeds of many plants.

Properties.—It is soluble in cold, but insoluble in

* Strange to say, the venom of the rattlesnake is isomeric with the "whites of eggs."

hot HO. At a temperature of 145° F. it coagulates. This change we always see in the cooking of eggs. Alcohol, corrosive sublimate, acids, creosote, etc., have the power to coagulate albumen. In cases of poisoning by these substances it is therefore a valuable antidote, as it wraps them up in an insoluble covering, and so protects the stomach. Albumen seems to have the properties of an acid and a base. It coagulates with an acid by uniting with it as a base. It coagulates with a salt by uniting with its base as an acid. It exists in two amorphous conditions—as a liquid in the sap of plants, the humors of the eye, serum of blood, etc.; as a solid in the seeds of plants and the nerves and brains of animals.

Vegetable Albumen.—If the water used in making starch from potatoes be boiled, it will become turbid and deposit a flaky white substance identical with the whites of eggs, and therefore named vegetable albumen.

FIBRIN constitutes chiefly the fibrous portion of the muscles. If a piece of lean beef be washed in clean HO until all the red color disappears, the mass of white tissue which will remain is called fibrin. Like albumen, it exists in two forms—as a liquid in the blood, and as a solid in flesh and the seeds



Fibrin, or Muscle.

of plants. The clotting of blood is due to the coagulation of the fibrin.

Vegetable Fibrin—Gluten.—If wheat flour be made into a dough, and then kneaded in water until all the soluble portion is washed away, the tough glutinous mass which will remain is called *gluten*. It is identical in composition with fibrin, and is therefore named vegetable fibrin. We obtain it as a gum when we chew wheat, thereby dissolving the starch. It exists most abundantly in the bran of cereal grains. Example: Wheat.

CASEIN is found in the curd of milk (whence the name, *caseum*, cheese), in the blood, peas, and beans. The curdling of milk is due to the coagulation of its casein. When milk sours, its lactic acid combines with the alkali present, and precipitates the casein, which is only soluble in HO containing some alkali. The rennet (the dried stomach of a calf), used in making cheese, acts in the same manner.

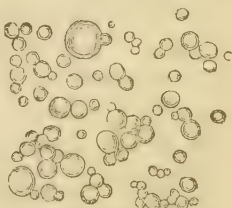
Vegetable Casein.—By treating peas as we do potatoes in forming starch, and then adding a little acid to the water which is left after the starch settles, an albuminous substance is deposited, which is identical with casein, and has received the name *vegetable casein*. The Chinese use it largely for cheese.

GELATIN.—Hot water dissolves a substance from animal membranes, skin, tendons, and bones, which, on cooling, forms a yielding tremulous mass called gelatin. As calves-foot jelly, soups, etc., it is well known. As an article of food it is of very little nu-

tritive value. It may answer to dilute a stronger diet, but of itself does little to build up the body of an invalid. Beef-tea is by far more strengthening than jellies or blanc-mange. *Glue* is a gelatin made from bones, hoofs, horns, etc., by boiling in HO and then evaporating the solution. *Isinglass* is the purest gelatin, and is obtained from the air-bladders of the cod, sturgeon, and other fish. *Size* is gelatin prepared from the parings of parchment, the thinnest kind of skins. It is used for sizing paper to fill up the pores and prevent the ink from spreading, as it does on unsized or blotting-paper.

Vegetable Gelatine is familiar to us in the form of blanc-mange and the fruit-jellies. It is nearly like starch or grape-sugar in its composition. It is called *Pectine* (see page 159). It is found in Iceland moss, grapes, apples, quinces, and other fruits.

MILK is a natural emulsion, composed of exceedingly minute globules diffused through a transparent liquid. The globules consist of a thin envelope of casein filled with butter. Being a trifle lighter than HO, they rise to the surface as cream. Churning breaks these coverings, and gathers the butter into a mass. Milk contains some sugar, and this, by the action of the O of the air changes to lactic acid, which gives the peculiar taste to sour milk. The casein seems to act as a ferment in hastening this oxydation. In



Milk under Microscope.

churning, the cream always "turns," because O is rapidly absorbed as the milk is stirred, and lactic acid formed. Milk sours in the stomach by the action of the acids, which convert it into lactic acid.

BONES consist of organic and mineral matter combined.

ANALYSIS. (*Berzelius.*)

Gelatin	32.17
Blood-vessels	1.13
Phosphate of lime.....	51.04
Carbonate of lime.....	11.30
Fluoride of calcium	2.00
Phosphate of magnesia.....	1.16
Chloride of sodium	1.20
	100.00

By soaking a bone in HCl the mineral matters will all be dissolved, and the organic matter left in the original shape of the bone, but soft and pliable. If, instead, the bone be burned in the fire, the organic matter will be removed and the mineral left white and porous. The blood circulates freely through the bones, however hard they may seem to be. If a little madder be mixed with the food of pigs, it will tinge red all their bones. If the madder be given at considerable intervals, it will make streaks of white and red bone alternately.

Putrefaction.—Owing to the complex structure of albuminous substances, and the presence of the fickle

nitrogen, they readily oxydize and form entirely new compounds. This breaking up is called putrefaction. The P and S present in flesh especially, take up the H in hot haste, and flying off as sulphuretted hydrogen (HS) and phosphuretted hydrogen (PH₃), salute our olfactories with their well-known odors. These poisonous and offensive gases abounding near slaughter-houses and similar establishments, make them so unhealthy. Any portion of an albuminous substance thus putrefying may act as a ferment. This probably explains the danger physicians incur in dissecting a dead body. The least portion of the decomposing matter entering their flesh, through a scratch even, is liable to be fatal. The presence of an albuminous substance always hastens decay. The white, or sap wood, contains some N, and so this rots very quickly. Timber steeped in a solution of corrosive sublimate (kyanized) is rendered almost indestructible, because that salt coagulates the albumen. The absence of HO retards chemical change, and therefore meats, apples, etc., are preserved by drying. Salt acts somewhat in the same way by absorbing the juice of the meat, and, while it covers it as brine, wards off the attacking O; but as it dissolves some of the salts and other valuable elements of the meat, it makes it less nutritious.

DOMESTIC CHEMISTRY.

In the chemistry of housekeeping there are some points not yet spoken of, and they may now be profitably discussed.

MAKING BREAD.—Flour consists of gluten, starch, and a little gum and sugar. There is also about two per cent. of ash, about one half of which is phosphate of lime; but these mineral constituents are found mainly in the bran. In mixing the “sponge,” the process is purely mechanical. The water used moistens the starch, dissolves the albumen, sugar, and gum, and causes the gluten to cohere. When the sponge is set aside in a warm place to rise (as heat favors chemical change), the yeast, yeast-cake, or emptyings, as the case may be, induces a rapid fermentation, converting the sugar into alcohol and CO_2 . This gas is diffused through the mass, and struggles to escape, but is retained by the tenacious and viscid dough, causing it to “rise.” The next step includes the addition of fresh flour, and a laborious process of “kneading.” The latter, so essential to good bread, diffuses the half-fermented sponge uniformly through the dough, and thus spreads the continued fermentation throughout the loaf; it also breaks up into smaller ones the bubbles of gas entangled in the gluten, and thereby makes the bread

fine-grained. The dough is now "moulded" into loaves. When placed in the hot oven, the first effect is to increase the fermentation. Some of the starch is turned into sugar to supply material, the heat expands the CO_2 , changes the alcohol to vapor and the water to steam. All these by their expansive force rapidly increase the size of the loaf. When the whole loaf has been heated to about 350°F. , the fermentation is checked, and if the temperature of the oven is right, the cells of the bread will have sufficient strength to retain their form after the gas and vapors have escaped. If the heat is not sufficient, or if there is too much water in the dough, the CO_2 escapes, and the cells, not having hardened sufficiently, collapse, and the bread is "slack-baked." If the oven is too hot, a crust forms over the surface of the loaf, which prevents the escape of the CO_2 , so it accumulates at the centre, making the bread hollow. A part of the starch in the crust is converted by the heat into gum (dextrine), and if it be burnt, this is disorganized, the volatile gases driven off, and the carbon left. A shiny coat is given to the loaf ("rusk") by moistening the crust after the bread is baked, thus dissolving some of the gum, which quickly dries on returning it to the oven.

Milk-emptyings is sometimes used in making bread. In this case, the mixture of flour and milk, kept at a temperature of 90° , develops yeast, which produces fermentation. If the heat is over 90° , the yeast plant is killed; if lower, it is not formed. In the

latter case, the milk is merely turned to lactic acid. Oftentimes, too, the side of the dish, near the fire, may be warm enough to produce yeast and to generate CO_2 and alcohol, while on the opposite side lactic acid is being formed. A uniform temperature is necessary, and this can best be obtained by placing the dish of emptyings in a kettle of warm water on the stove hearth, where the temperature can be kept very near the requisite 90° .

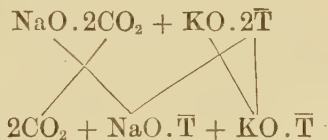
STALE BREAD.—New bread consists of nearly one half water. In stale bread this disappears. It has, however, only combined with the solid portions chemically, and may be brought to view by heating the loaf in a close tin vessel.

AERATED BREAD.—Flour and salt are put in a revolving copper globe, into which HO charged with CO_2 is admitted. When mixed well, on turning a stop cock, the dough is driven out, by the elastic force of the gas, into pans ready for baking.

SOUR BREAD is caused by the first stage of the fermentation not being stopped soon enough, and the second stage commencing, in which acetic acid is formed. This may be neutralized by an alkali, as saleratus ($\text{KO} \cdot 2\text{CO}_2$), or soda ($\text{NaO} \cdot 2\text{CO}_2$).

PAN-CAKES are raised by the addition of some ferment, as yeast, but the second, or acetous stage, is always reached. The "batter" now tastes sour, and is sweetened by saleratus or soda. The acetic acid combines with the KO (if saleratus is used), forming acetate of potassa, a neutral salt which remains, and the CO_2 bubbles up through the batter, making it "light."

RAISING BISCUIT.—In raising biscuit or cake, soda and cream of tartar are most commonly used. The latter is a bitartrate of potassa, and the reaction is as follows :



Cream of tartar is now often adulterated with plaster, lime, chalk, or flour. By dissolving in water these can be detected, as they form an insoluble precipitate; but in milk, as commonly used in cooking, they are not noticed. Common “baking-powders” contain simply cream of tartar and soda. Professor Hosford’s powders are scientific. They contain phosphate of lime and soda. The reaction is the same as that just described, while phosphates of lime and soda are formed, both of which are materials for bone-making. Soda and HCl are also used in baking. By heat both constituents are resolved into HO, CO₂, and NaCl. The HO and CO₂ raise the bread, while the common salt seasons it. There is a difficulty in procuring pure acid and in mixing the ingredients in their combining proportions.

Bread Dietetics.—It is doubtful whether ordinary yeast-powders or cream of tartar and soda make as healthy food as the regular process of fermentation. There is frequently a portion of the powders left un-

combined, and always a salt formed which may injure the gastric juice. Sometimes, indeed, we find biscuit and cake yellow, and even spotted with bits of saleratus; yet such food must be "eaten to save it." A most wretched mistake! Better throw away pans of cake and biscuit than torment Nature with such nauseous, poisonous preparations. Sal-volatile or carbonate of ammonia is often used by bakers for raising cake. This should volatilize into two gases, NH_3 and CO_2 , on the application of heat, but in practice a portion is left commonly hidden in the cake to work injury to the inoffensive stomach.

TOASTING BREAD.—By toasting bread it becomes much more digestible, as the starch is converted largely into gum, which is soluble. The charcoal which may be formed when the heat has disorganized the bread and driven off the water, also acts favorably on the stomach by absorbing in its pores noxious gases, as in "crust coffee."

COOKING POTATOES.—A raw potato is indigestible, but by cooking, the starch granules absorb the water of the potatoe, burst, and make it "mealy." If the potatoe contains more HO than the starch can imbibe, it is called "watery."

COOKING MEAT.—All fried food is unhealthy, since the fat is partly disorganized by the heat, and therefore becomes rancid on the stomach. Broiling and boiling are the most wholesome methods of cooking. In the former no butter should be used, and the juices should not be pressed out of the meat, but the heat

should be intense enough to sear over the outside instantly, and prevent "dripping" on the coals. In the latter, the water should boil when the meat is put in, so as to coagulate the albumen upon the outside, close the pores, and thus keep the juices of the meat within, otherwise it will become tough, and much also of its value will be lost. In making soup, on the contrary, as the object is to extract the juices of the meat, cold water should be used. It should be heated slowly, and boiled only for a few moments just before it is taken off from the fire. Long continued boiling would coagulate that which should remain dissolved in the soup. In baking, the oven should be very hot at first, to prevent the meat from becoming dry and unsavory. When meat burns, the heat has become so intense as to disorganize the flesh, driving off the HO and volatile gases, and leaving the C.

WATER IN COOKING.—The solvent power of soft water is greater than that of hard water. For this reason, in making soup, tea, etc., the former should be used; in boiling meats and cooking vegetables, where the object is not to extract the flavor or juices, the latter is preferable. Sometimes in cooking very delicate vegetables, as onions, the hardness of the water must be increased by adding salt to prevent their sweetness from dissolving. Salt is not put into vegetables, when boiling them, so much to flavor them as to preserve their aroma, which, if lost, no subsequent salting will restore. Peas and beans will not

cook soft in hard water, because the mineral matter hardens the casein they contain. A soup cannot be made of salt meat.

QUANTITY OF FOOD REQUIRED.—To repair the constant waste of the body, we each require about 800 lbs. of food, 1500 of water, and 800 of oxygen per annum. A ton and a half of material is thus needed each year to preserve intact our corporeal system. We take in each day about 10 lbs. of matter, yet may not gain an ounce in weight. This large amount passing through the mould of our body is all burned—*i. e.*, combines with O. This must be a renewed proof of the statement made under the subject of oxygen, that the vital principle does not prevent decay, but only regulates it, and that the moment we begin to live we begin to die.

THE EFFECT OF FOOD.—There is an ancient saying, “Tell me what a man eats and I will tell you what he is.” A man’s mind sympathizes so intimately with his body, that through the body the soul itself may be gradually animalized by gross food. The coarse feeder and the fine feeder become as different in their feelings as they are in their food. Animal food inflames; vegetable, calms. The passionate require a vegetable diet, while the phlegmatic may stimulate with flesh. Compare, for example, the dreamy vegetarian Hindoo with the fierce, meat-eating Indian.

THE DIVISIONS OF FOOD.—All food is divided into two general classes—“*heat-making*” and “*muscle-*

making," or respiratory and nutritive. The former comprises all such articles as are burned in our corporeal stove, as wood is in a furnace, mainly to produce heat. Example: Alcohol, starch, sugar, gum, fat, butter, etc. The latter includes such as are transformed into flesh and bone, and thus build up our bodies in some manner. Example: Lean meat, bread, milk, etc. Each of these contains a mixture of both to a certain extent, but is mainly either respiratory or nutritive. Example: Fat is deposited in cells which are probably nutritive, and, on the other hand, bread contains starch, which is respiratory.

NUTRITIVE VALUE OF FOOD OF DIFFERENT KINDS.—The following table, from Liebig, illustrates this subject:

	Nutritive.	Respiratory.
Cows' milk.....	1	3.
Beans.....	1	2.2
Peas.....	1	2.3
Fat mutton.....	1	2.7
Fat pork.....	1	3.
Beef.....	1	1.7
Veal.....	1	.1
Wheat flour.....	1	4.6
Oat meal.....	1	5.
Rye flour.....	1	5.7
Barley.....	1	5.7
Potatoes (white).....	1	8.6
Potatoes (blue).....	1	11.5
Rice.....	1	12.3
Buckwheat.....	1	13.

Sugar, alcohol, oil, etc., are heating and fattening. They make no muscle, no brain, no nervous tissue.

The bran of wheat contains largely the mineral matter we need for our bones and teeth and the nutritive food for our muscles. The whiteness of fine flour ("bolted" from its bran) is given to it by its starch. Our bones and muscles call loudly for the flour unbolted, as Nature designed it to meet our wants. The nutritive value of corn is very great, since it is rich in fat and nitrogenous matter. Rice is less valuable, the proportion of plastic material being only half that of wheat. The potato contains but 25 per cent. of nutritive (plastic) matter, but it is easily digested, and answers well mixed with more nitrogenous food. The lean of all meat abounds in nitrogen, and is about equally nutritious if equally well digested. Fat meat, especially pork, possesses carbonaceous matter in excess.

CLIMATE PRESCRIBES THE KIND OF FOOD.—The Esquimaux Indian, with a climate many degrees below zero, needs much fire in his stove; so he lives mainly on fats. Tallow candles constitute his sweetmeats—twelve pounds making a luxurious dessert. Dr. Kane tells us that they would steal the half-burned wicks out of his candlesticks and draw them slowly between their teeth, to secure the adhering grease. Indeed, their idea of heaven is said to be that there the righteous will live in ice-huts, and feast forever on blubber. An American living in the Arctic regions soon acquires much of an Esquimaux's love for fats and oils. Nature has providentially provided there that kind of food, and not much else. Turn now to

the tropics, where the temperature is so high that all one's attention is taken up in keeping cool, and we find an entire change in the diet of the inhabitants. The natives confine themselves almost entirely to vegetables, and with this watery fuel reduce the heat of their bodies to the lowest point.

A MIXED DIET REQUIRED.—Nature seems to prescribe a mixed diet, to supply both wants of the system, and has, to some extent, mixed them herself in the various kinds of food. The Frenchman eats oil on his salad, the Yankee bakes beans with his pork, the Italian begs a bit of cheese for his maccaroni, the Irishman drinks buttermilk with his potatoes, the Hindoo pours rancid butter on his rice, while the Chinaman seasons his with pea cheese. No amount of starch or fat would support life. A man would starve on sugar or butter alone. The nitrogenous or nutritive element must be added. The season also regulates our diet. In the winter the highly respiratory buckwheat, with butter and syrup, is perfectly palatable, while in summer acid drinks, watery vegetables, and a simple unstimulating diet are equally enjoyed.

CONCLUSION.

CHEMISTRY OF THE SUNBEAM.—All those various plant products of which we have spoken in Organic Chemistry, when burned, either in the body as food or in the air as fuel, give off heat. This was garnered in the plant while growing, and came from that great source of heat—the sun. Thus all vegetation contains the latent heat of the sunbeam, ready to be set free upon its own oxydation. The coal even, derived as it is from ancient vegetation, hidden away in the earth, is thus a mine of reserved force. Those black diamonds we use as fuel become, in the eye of science, crystallized sunbeams, fagots of force, ready to impart to us at any moment the heat of some old carboniferous day. As we warm ourselves by our fires, or sit and read by our oil and gas lights, how strange the thought that their light and heat streamed down upon the earth ages ago, were absorbed by those grotesque leaves of the old coal forests, and kept safely stored away by a Divine care, in order to provide for our comfort! To carry the idea still further, we see that the present warmth of our bodies all comes from the same source—the sun. It mostly fell in the sunbeams of last summer upon our gardens and fields, was preserved in the

potatoes, cabbage, corn, etc., we have eaten, as fuel, and to-day reappears as heat and motion.

CHANGES OF MATTER.—Chemical changes are taking place wherever we look—on land or sea. The hard granite crumbles and moulders into dust. The stout oak takes in the air and solidifies it; takes up the earth and vitalizes it; changes all into its own structure, and proudly stands monarch of the forest. But in time its leaves turn yellow and sere, its branches crumble, itself totters, falls, and disappears. Our own bodies seem to us comparatively stable, but, with the rock and the oak, they too pass away. All Nature is a torrent of ceaseless change. We are but parts of a grand system, and the elements we use are not our own. The water we drink and the food we eat to-day may have been used a thousand times before, and that by the vilest beggar or the dirtiest earth-worm. In Nature all is common, and no use is base. She keeps no selected elements done up in gilt papers for sensitive people. Those particles of matter we so fondly call our own, and decorate so carefully, a few months hence may have dragged boats on the canal, or waved in the meadow as grass or corn. From us they will pass on their ceaseless round to develop other forms of vegetation and life, whereby the same atom may freeze on arctic snows, bleach on torrid plains, be beauty in the poet's brain, strength in the blacksmith's arm, or beef on the butcher's block. Hamlet must have been somewhat more of a chemist than a madman

when he gravely assured the king that "man may fish with the worm that hath eat of a king, and eat of the fish that hath fed of the worm." Life and death are thus, throughout Nature, commensurate with and companions of each other. Oxygen is the destroyer. It tears down every living structure, and would bring all things to rest in ashes. The sunbeam is its antagonist. It rebuilds and reinvigorates.

THE SUN THE SOURCE OF POWER.—The sun warms, cultivens, and animates the earth. In the laboratory of the leaf it works the most wonderful chemical changes. We see its handiwork in the building of the forest, the carpeting of the meadow, and the tinting of the rose. On the ladder of the sunbeam water climbs to the sky, and falls again as rain. The very thunder of Niagara is but the sudden unbending of the spring that was first coiled by the sun in the evaporation from the ocean. Up to the sun, then, we trace all the hidden manifestations of power. Yet the force that produces such intricate and wide-extended changes is but one twenty three hundred millionth part of the tide that flows in every direction from this great central orb. But what is our sun itself save a twinkling star beside great suns like Sirius, and Regulus, and Procyon, whose brilliancy in the far-off regions of space drowns our little sun as the dazzling light of day does the smouldering blaze of some wandering hunter?

Thus have we traced some of the wonderful processes by which this world has been arranged to supply the varied wants of man. Wherever we have turned, we have found proofs of a Divine care planning, conforming, and directing to one universal end, while from the commonest things and by the simplest means the grandest results have been attained. Thus does Nature attest the sublime truth of Revelation, that in all, and through all, and over all, the Lord God omnipotent reigneth.

APPENDIX.

PROBLEMS.

MATHEMATICS OF CHEMISTRY.—In solving the problems given on the 17th page, some may prefer to use proportion. The following will suggest the method:

The equivalent of the given constituent : equivalent of the compound :: weight of the constituent : weight of the compound.

Problem 1. How many lbs. of HO are there in a cwt. of $\text{SO}_3 \cdot 2\text{HO}$?

Solution—

$2\text{HO} = 18 =$ equivalent of the given constituent.

$\text{SO}_3 \cdot 2\text{HO} = 58 =$ equivalent of the compound.

$x =$ weight of the constituent.

100 lbs. = weight of the compound.

$18 : 58 :: x : 100 \text{ lbs.}$

$x = 31\frac{1}{3} \text{ lbs.}$

Prob. 2. How much sodium is there in 20 gr. of soda (NaO)?

Solution—

Na = 23 = equivalent of the given constituent.

NaO = 31 = equivalent of the compound.

x = weight of the constituent.

20 gr. = weight of the compound.

$$23 : 31 :: x : 20 \text{ gr.}$$

$$x = 14\frac{2}{3}\frac{6}{1} \text{ gr.}$$

Prob. 3. How much carbonate of lime can be formed from one drachm of C?

Solution—

C = 6 = equivalent of the given constituent.

CaO.CO₂ = 50 = “ “ “ compound.

1 dr. = weight of the given constituent.

x = weight of the compound.

$$6 : 50 :: 1 \text{ dr.} : x.$$

$$x = 8\frac{1}{3} \text{ drachms.}$$

Prob. 4. How much CO₂ would be required to neutralize 2 lbs. of potash?

Solution.—First we find how much KO.CO₂ two lbs. of KO will make, and then how much CO₂ will be contained in that amount of the salt.

(1.) KO = 47 = equivalent of the constituent.

KO.CO₂ = 69 = equivalent of the compound.

2 lbs. = weight of the constituent.

x = weight of the compound.

$$47 : 69 :: 2 \text{ lbs.} : x = 2\frac{1}{4} \text{ lbs.} = \text{weight of KO.CO}_2.$$

(2.) $\text{CO}_2 = 22 =$ equivalent of the constituent.

$\text{KO.CO}_2^* = 69 =$ equivalent of the compound.

$x =$ weight of the constituent.

$24\frac{4}{7} =$ weight of the compound.

$$22 : 69 :: x : 24\frac{4}{7} \text{ lbs.}$$

The remaining problems can be used throughout the term at the discretion of the teacher, whenever the appropriate subject is under consideration in the class.

Prob. 5. What weight of O is contained in 60 gr. of KO.ClO_5 ?

Prob. 6. How much KCl will be formed in preparing 80 gr. of O?

Prob. 7. How much H can be made from 10 lbs. of Zn?

Prob. 8. How much H can be made from 50 lbs. of water?

Prob. 9. How much saltpetre will be required to make 18 lbs. of aquafortis?

Prob. 10. How much oil of vitriol will be required to decompose 6 lbs. of saltpetre?

Prob. 11. How much HO will be decomposed by one drachm of K, and how much KO will be formed?

Prob. 12. What weight of nitrous oxyd will be formed from the decomposition of 6 oz. of nitrate of ammonia?

Prob. 13. How much sal-ammoniac would be required to make 2 lbs. of NH_3 ?

* Some late authorities give the equivalent of K as 39.2, which would slightly change this result.

Prob. 14. How much CO_2 will be formed in the combustion of 30 gr. of CO ?

Prob. 15. What weight of carbonate of soda would be required to evolve 12 lbs. of CO_2 ?

Prob. 16. What weight of bicarbonate of soda ($\text{NaO} \cdot 2\text{CO}_2$, "soda") would evolve 12 lbs. of CO_2 ?

Prob. 17. What weight of C is there in a ton of CO_2 ?

Prob. 18. How much O is consumed in burning a ton of C ?

Prob. 19. In burning a charge of 10 lbs. of gunpowder, find the weight of the several products formed.

Prob. 20. What weight of common salt would be required to form 25 lbs. of muriatic acid (HCl)?

Prob. 21. HCl of a specific gravity of 1.2 contains about 40 per cent. of the acid. This is very strong commercial acid. What weight of this acid could be formed by the HCl acid gas produced in the reaction named in the preceding problem?

Prob. 22. What weight of hydriodic acid (HI) is formed from a drachm of iodine?

Prob. 23. What weight of Glauber salt can be formed from 100 lbs. of oil of vitriol?

Prob. 24. What weight of S is there in 10 gr. of sulphide of hydrogen?

Prob. 25. How much O is required to change a lb. of SO_2 to SO_3 ?

Prob. 26. How much phosphorus in 40 lbs. of phosphate of lime?

Prob. 27. How much P in 40 lbs. of the superphosphate of lime?

Prob. 28. How much phosphate of lime will an oz. of P make?

Prob. 29. How many lbs. of HO in 186 lbs. of $\text{SO}_3 \cdot 3\text{HO}$?

Prob. 30. How much CO_2 is formed in the combustion of one ton of C?

Prob. 31. What weight of S is there in a ton of iron pyrites?

Prob. 32. What weight of copperas could be made from 500 lbs. of iron pyrites?

Prob. 33. What weight of H is there in a pound of heavy carburetted hydrogen?

Prob. 34. How much O would be required to oxydize the metallic copper which could be reduced from its oxyd by passing over it, when white-hot, 20 gr. of H gas?

Prob. 35. How much O would be required to oxydize the metallic iron which could be reduced in the same manner by 10 gr. of H gas?

Prob. 36. What weight of N is there in 10 lbs. of $\text{NH}_3 \cdot \text{HO}$?

Prob. 37. How much $\text{KO} \cdot \text{ClO}_5$ would be required to evolve sufficient O to burn the H produced by the decomposition of 2 lbs. of HO?

Prob. 38. How much H must be burned to produce a ton of water?

Prob. 39. How much S is there in a lb. of SO_2 ?

THE ALKALIES.

Problem 40. As soda is used so extensively in the arts, it is of great importance to all consumers of soap, glass, etc., that it should be manufactured as cheaply as possible. Leblanc's process of making it from common salt is now universally adopted. The operation comprises two stages: (1) Changing common salt into sulphate of soda; and (2), the changing of this sulphate of soda into carbonate of soda.

The first operation is performed in large cast-iron pans, about 12 inches deep at the centre, and 9 feet diameter. A charge of 500 lbs. of salt is thrown into one of these pans with about an equal weight of SO_3 , and heated. The sulphate of soda is formed with an evolution of HCl fumes. These fumes are conducted into the bottom of a vertical flue, filled with pieces of coke, wet with constantly dripping water. This HO absorbs the gas, and forms a very weak *muriatic acid*, in immense quantities.

The second stage consists in grinding the Glauber salts (sulphate of soda) with an equal weight of chalk ($\text{CaO} \cdot \text{CO}_2$), and half its weight of coal. This mixture is heated and stirred until well melted, when it is raked out to cool. This mass is called "*black ash*." The chemical change that has taken place is very simple; the charcoal deoxydized the salt, changing the sulphate of soda into the sulphuret of sodium. The sulphuret of sodium then reacted with

the carbonate of lime forming the sulphuret of calcium and the carbonate of soda, as follows :



The carbonate of soda alone being soluble in HO, is dissolved out of the black ash, and then crystallized, producing the soda-ash of commerce.

The muriatic acid, which is an incidental product of the first stage, is used in making chloride of lime, so extensively employed in bleaching. The sulphuret of calcium has always been a waste product ; but at the late exposition at Paris (1867), blocks of sulphur, of tons weight each, were exhibited, which had been extracted from it by a process not yet divulged. It is said that 200,000 tons of common salt are annually used in the alkali manufactories of England.

Find how much "soda" is formed from 500 lbs. of salt.

Prob. 41. Find the amount of Glauber salt produced in the first step, with the charge just named.

Prob. 42. Find the amount of HCl produced.

Prob. 43. Find how much sulphuret of sodium is formed in the second step.

Prob. 44. Find how much sulphuret of calcium is made.

Prob. 45. Find how much sulphur could be saved (if none were lost) from the CaS.

Prob. 46. How many lbs. of HCl would be required to neutralize sufficient carbonate of ammonia to form a 30 lb. cake of sal-ammoniac ($\text{NH}_4 \cdot \text{Cl}$) ?

Prob. 47. How much S is there in a ton of plaster (gypsum)?

Prob. 48. How much aluminum is there in a ton of clay?

Prob. 49. How much K is there in 10 lbs. of alum?

Prob. 50. How much white-lead ($\text{PbO} \cdot \text{CO}_2$) could be made from a lb. of litharge?

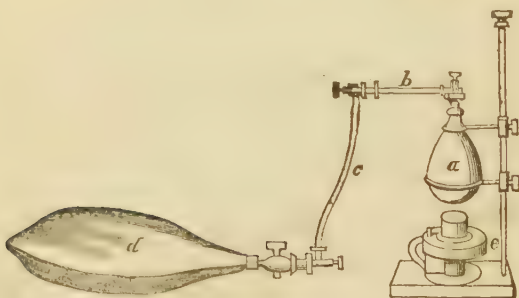
Prob. 51. How many lbs. of C would be required to reduce 40 tons of brown Hematite ($2\text{Fe}_2\text{O}_3 \cdot 3\text{HO}$)?

Prob. 52. In 60 lbs. of heavy spar (sulphate of baryta) how much S is there?

Prob. 53. How much alum can be made from 1 cwt. of potash?

THE METALLOIDS.

(Page 18.) OXYGEN.—In making this gas, a copper flask and rubber tubing should be used, as it is by far the cheapest apparatus. Great care should be



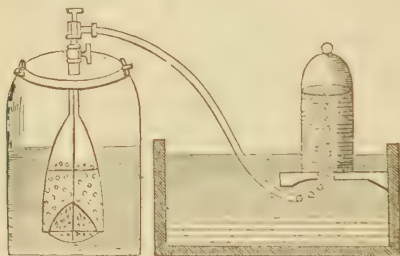
- a Copper retort.
- b A copper tube leading from it.
- c Tube of india-rubber to convey the gas to a gas-bag, gasometer, or pneumatic trough.
- d Gas-bag.
- e Spirit-lamp.

taken in pulverizing the KO , ClO_5 , as a pressure of more than 10 lbs. is liable to produce an explosion. For the experiments with the watch-spring, phosphorus, etc., common "specie jars" will be found very convenient, or, in necessity, any wide-mouthed bottles which can be obtained of a druggist.—The author will be pleased to correspond with any teacher who may be desirous of information concerning the apparatus which is needed, and the simplest method of performing the various experiments. Priced lists of apparatus, chemicals, etc., can be obtained, on application, from Messrs. J. Nellegar & Co. (late Messrs. Dexter & Nellegar), Albany, N. Y.

(Page 34.) NITROUS OXID.—A special apparatus is necessary both for preparing and inhaling this gas safely. This consists of a glass retort—as shown in the cut—a wash-bottle, and in addition a gas-bag of from 20 to 50 galls. capacity for storing the gas, and a smaller bag of from 3 to 5 galls., with a wide, wooden mouth-piece for inhalation. It is well to pass the gas through a large wash-bottle, as shown in the cut on page 41, *half full of HO*, thence by a rubber tube directly into the large gas-bag. Before making the gas, pour into the bag a couple of gallons of HO : by standing in the bag over this the gas will be purified in a few hours. When about to administer the gas, let the subject grasp his nose firmly between his thumb and forefinger: then, inserting the wooden mouth-piece, be careful that he does not inhale any of the external air, but takes full, deep

breaths in and out of the gas-bag. Watch the eye of the subject, and notice the influence of the gas. Commonly, the best effect is not reached until he begins to surge backward and forward.

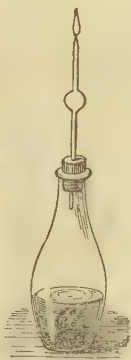
(Page 43.) The zinc for making hydrogen should be granulated. This is easily effected by pouring the melted metal slowly from the ladle into a basin of HO. A common junk-bottle, fitted with a cork and a glass tube, will answer for the evolution of the gas, but a "hydrogen generator," as sold by apparatus dealers, is much more satisfactory. In experi-



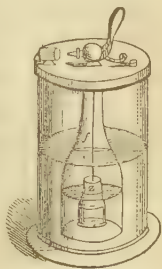
Hydrogen Generator.

menting with H, great care must be used not to ignite the jet of gas until all the common air has passed out of the flask; otherwise a severe explosion will ensue. It is a safe precaution to test the gas by passing it in bubbles up through HO, and igniting them at the surface; the force of the combustion will indicate if there be any danger. It must not be kept for any great length of time in bags, as the air will gradually force itself in, and the gas will

partly pass out by the law of diffusion, thus forming a mixture which it is dangerous to ignite. The adjoining illustration of a jet of burning H is a representation of what is called "The Philosopher's Lamp." In using the "mixed gases," the utmost care is requisite. The gases may be passed into a gas-bag, made of a common bladder, furnished with a stop-cock. A clay tobacco pipe may be attached to it by means of a bit of rubber tubing. A plate of good soapsuds makes the outfit complete. Blow the bubbles with the gases in the bag, either in the air, or on the tin plate, but be cautious not to ignite them until the stop-cock is turned, and the bag withdrawn from the dish. Pure H bubbles may be blown in the same manner: if out of doors, they will float off to a great distance. H may be better purified for inhaling, by passing it through a solution of potash, with some alcohol added to it. The action of platinum sponge is best shown by the instrument represented in the cut. It was formerly used by chemists as a convenient way of obtaining a light in the laboratory. Friction matches have superseded such clumsy inventions. The experiments with the compound blowpipe, as shown in the frontispiece, Doberceiner's Lamp.

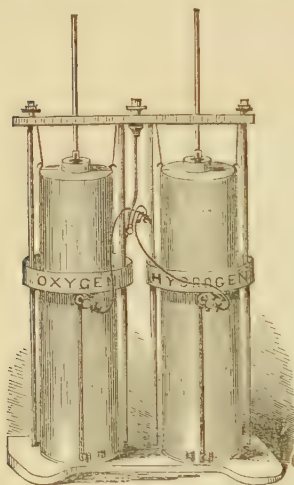


The Philosopher's Lamp.



Doberceiner's Lamp.

can be given either by the use of gasometers, or, in their stead, rubber gas-bags may be substituted at a



Gasometer.

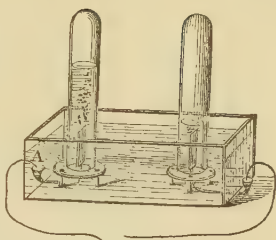
much lower price. The H gun—which is simply a tin tube, closed at one end, and provided with a cork at the other, having a priming-hole at the side—may be filled over the Philosopher's Lamp when not ignited. The gas is allowed to pass in until the gun is about a fifth full, as nearly as one can guess.

Hydrogen has long been considered to be a *gaseous* metal as mercury is a *liquid* one. It plays the part of a metal in various compounds; it is electro-positive, like most of the metals. For these and other reasons it has been ranked as a metal. Prof. Graham has lately announced that he has discovered its metallic base. H is found largely incorporated in meteoric iron. It is also a prominent constituent of many of the stars, and the wonderful flames seen to play about the sun during an eclipse consist of burning H.

(Page 47.) WATER is analyzed by the action of the galvanic current in the manner shown in the following cut. We analyze it when we put upon our coal

fire cinders wet with HO. The HO adds to the intensity of the fire, and "makes it burn better," as we say.

(Page 55.) THE DIAMOND.—Although the diamond is simply pure carbon, yet it has never been made



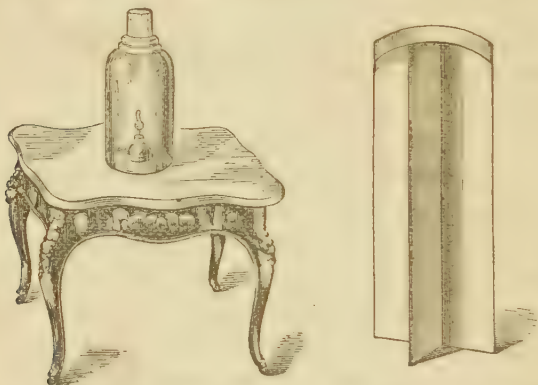
Analysis of Water.

by any chemical process. Minute diamonds, it is said, have been separated from carbon compounds by long-continued voltaic action, but they were invisible except by a microscope. The value of the diamond varies with the market; the *general* rule is as follows: a gem ready for setting, of one carat weight, is worth \$40 to \$60; beyond this size, its value increases according to the square of its weight. The *Kohinoor* (mountain of light) weighs 103 carats, and is valued at \$10,000,000.

(Page 64.) CARBONIC ACID.—The poisonous action of CO_2 is thought to be due more to its shutting off the O than to any positive ill-qualities which it possesses. It is said that 15 per cent. of CO_2 will not produce any immediate effect if the proportion of O be correspondingly increased.

Ventilation is thought by many to be perfectly provided for if there be a ventilator placed at the top of the room, presenting one small opening for the egress of the bad air. To show the fallacy of this, we need only perform the experiment represented in

the adjoining cut. The bottle is fitted with a tin cover, through which a tube is inserted. The jar represents a room sealed tightly on all sides against



the incoming of the air, and with only one opening for ventilation. Place a lighted candle at the bottom, and it will soon be extinguished, no O seeming to come in to feed the flame. Place now in the tube a slide, composed of two slips of tin soldered at right angles to each other, thus dividing the tube into four longitudinal portions. The lighted candle will burn freely, and a bit of smoking paper held at the top of the tube will reveal a current passing downward through two of the openings, and a current passing outward through the opposite ones. This shows very clearly the effect of a division in the opening used for ventilation. Of course, no room can be made as nearly air-tight as the bottle, since some air will come in at the sides, around the win-

dows, etc.; still, this experiment illustrates the imperfection of the ordinary ventilator. The necessity of some means of changing the air is shown by the fact, that two persons sleeping in a room 15 ft. square will vitiate the atmosphere in three hours, and so rebreathe it twice before morning, and then wonder why they wake up with a headache.

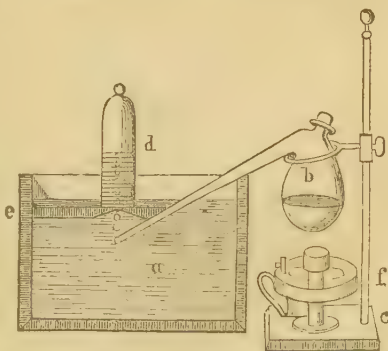
(Page 73.) CYANOGEN.—The pupil will here distinguish ferrocyanide of potassium from the ferricyanide. The latter is the *red prussiate of potash*. When the yellow prussiate is added to a salt of the sesquioxide of iron, *prussian blue* is formed. This is employed in water-colors and oil-paintings, and when dissolved in oxalic acid, constitutes *blue ink*.



Law of Diffusion

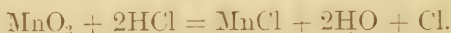
(Page 83.) THE LAW OF DIFFUSION may be finely illustrated by the experiment shown in the cut. The upper jar is to be filled with H, and the lower one with CO₂. The result will be that described in the text.

(Page 86.) CHLORINE.—In the arts, and for many experiments, Cl is made by simply



a Pneumatic trough. d Bell glass receiver.
b Retort. e Shelf in pneumatic trough.
c Lamp-stand. f Spirit-lamp.

heating, in a glass retort, black oxyd of manganese, with muriatic acid. The reaction is this :



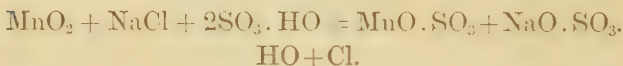
Indeed, most of the experiments in Cl may be performed by taking a deep glass jar, and placing at the bottom some chloride of lime. By pouring upon this a little dilute SO_3 , the Cl will soon fill the jar and dis-



Phosphorus in Cl.

place the air. Phosphorus will inflame spontaneously in Cl. The gas is very annoying, and the room must be thoroughly ventilated.

In preparing Cl, as mentioned in the text, take four parts of common salt and mix it thoroughly with three parts of black oxyd of manganese ; put this mixture in the retort, and pour upon it dilute SO_3 . The gas will be evolved abundantly. The reaction is as follows :



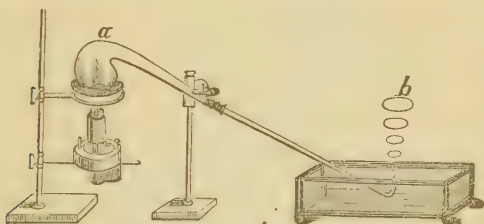
The gas should be collected over warm water, as it is largely absorbed by cold water. By passing the gas for some time through a bottle of HO, a solution will be formed which will perform all the experiments in bleaching very nicely. To illustrate this, pour some of the chlorine-water into a test-tube of HO blackened with a few drops of ink.

(Page 88.) BLEACHING POWDER is considered to be a mixture of the chloride of calcium and the

hypochlorite of lime—thus, $\text{CaCl} + \text{CaO} \cdot \text{ClO}$. It is produced in great quantities in the process of making sal-soda. (P. 233.)

(Page 93.) BICBORATE OF SODA ($\text{NaO} \cdot 2\text{BO}_3 + 10\text{HO}$) is used in soldering and in brazing, and also in “blow-pipe analysis.” When borax is melted with oxyd of chromium, it gives an emerald green; with oxyd of cobalt, a deep blue; with oxyd of copper, a pale green; with oxyd of manganese, a violet.

(Page 103.) PHOSPHIDE OF HYDROGEN is frequently made by nearly filling a retort with a strong solution



a Retort filled with solution of potash, with pieces of phosphorus in it.
b Rings of vapor, from the combustion of the phosphuretted hydrogen.

of KO, and then adding a few drops of ether and some small bits of phosphorus. The object of the ether is to prevent the explosion of the first bubbles of gas, as they come off, in the retort. The beak of the retort should dip under HO before applying the heat.

The following singular story is told of the probable discovery of phosphorus many years before that of Brandt, the reputed discoverer. A certain prince San Severo, at Naples, exposed some human

skulls to the action of several reagents, and then to the heat of a furnace. From the product he obtained a vapor which kindled at the approach of a light, and continued to burn aglow for months without apparently diminishing in weight. San Severo refused to divulge the process, as he wished his family vault to be the only one to possess a "*perpetual lamp*," the secret of which he considered himself to have discovered.

(Page 108.) In the text the theory of Dr. Draper is given; it is well, however, to remark that the latest foreign investigators hold that there is no free HCl in the stomach, and that the only acid present there is lactic.

(Page 115.) METALS OF THE ALKALINE EARTHS.—These are termed alkaline because they are caustic, and earths, because they are insoluble in HO. The



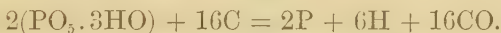
Lime Kiln.

annexed cut shows an improved form of lime-kiln, in which the process is continuous. At *a, b, c, d*, are the doors for fuel, ash-pit, etc. The limestone is fed at the top from time to time, while the lime is taken out at *f* as fast as formed.

Concrete is a cement of coarse gravel and *water-*

lime. It is of great durability. *Whitewash* is a mere "milk of lime." "*Hard finish*" is a kind of plaster in which gypsum is used to make the wall smooth and hard. "*Calceining*" is a process of whitening walls with a wash of plaster of paris, or whiting.

(Page 119.) PHOSPHATE OF LIME.—When bones are burned, a tribasic phosphate of lime is formed—thus, $3\text{CaO}.\text{PO}_5$. When this is heated with SO_3 , the change is as follows: $3\text{CaO}.\text{PO}_5 + 2(\text{SO}_3.\text{HO}) = \text{CaO}.\text{PO}_5.2\text{HO} + 2(\text{CaO}.\text{SO}_3)$. This mixture is sometimes called the superphosphate of lime, although the term belongs properly only to the $\text{CaO}.\text{PO}_5$. By filtering, the $\text{CaO}.\text{SO}_3$ is removed, and the superphosphate is sold as a fertilizer, or may be heated with charcoal to form P—thus:



(Page 129.) When iron is cast in large masses, the metal has time to crystallize, and this weakens it very much. When an immense cannon is cast, like the Fort Pitt gun, a stream of water is allowed to run through it to hasten the cooling process. When the melted iron is cooled in an iron mould, this chills the surface instantly, and makes it extremely hard. The product is called "*chilled iron*," and is used for safes and other burglar-proof instruments.

(Page 133.) COPPER.—Both lead and copper are found nearly pure, the former in Missouri and Northern New York; the latter near Lake Superior. In such cases, the extraction of the metal from the spar in which it is imbedded is very simple. The ore is

ground to powder in a stamp-mill, and then, by repeated washing, during which the metal sinks by its superior specific gravity, is separated from the spar, and is prepared for the furnace, where it is melted and cast into bars for the market. The ore, containing oxyd, or carbonate of copper, can readily be reduced by heating with charcoal and lime, as in the process of iron-smelting. The sulphurets, however, are reduced with much greater difficulty. They contain much iron pyrites, which must be removed. They are first roasted, to convert a part of the sulphurets of copper and iron into oxyds. They are then smelted, as we have described before, and the iron mostly passes off in the slag, while the copper is reconverted into a sulphuret. This is next roasted, and lastly heated to so high a temperature, that the sulphur leaves the copper as SO_2 , while the melted metal is drawn off, ready for the market.

(Page 138.) COBALT is a reddish-white metal, found in combination with arsenic. It received the name *cobaltus* from the miners, because its ore looked so bright that they thought they would obtain something valuable, but by roasting, it crumbled to ashes. They therefore thought they were mocked by the Kobolds—the evil spirits of the mines. The oxyd of cobalt makes a beautiful blue glass, which, when ground fine, is called *smalt*. It is used for tinting paper, and by laundry women to give the finished look to cambrics, linen, etc. Its impure oxyd, called *zaffer*, imparts the blue color to common earthenware and

porcelain. The chloride (CoCl) is used as a sympathetic ink. Letters written with a dilute solution of it are invisible when moist with the HO absorbed from the air, but on being dried at the stove, again become blue. If the paper be laid aside the writing disappears, but may be revived in the same manner. A winter landscape may be drawn with india-ink, the leaves being added with this ink. On being brought to the fire it will bloom into the foliage of summer.

MANGANESE is a hard, brittle metal, resembling cast-iron in its color and texture. It takes a beautiful polish. Its binoyd, the black oxyd of manganese, has been spoken of as used in the manufacture of O , Cl , etc. By fusing four parts of MnO_2 and three and a half parts of chlorate of potash with five parts of KO dissolved in a little water, a dark green mass is obtained called "*chameleon mineral*." If a piece of this be dropped into HO , the solution will undergo a beautiful change from green, through various shades, to purple. This is owing to the gradual formation of permanganic acid. The change may be produced instantaneously by a drop of SO_3 .

NICKEL is a grayish metal. Like cobalt, it is a constituent of meteorites. It is mined in Pennsylvania, in large quantities, by the United States Government, for making nickel cents. Its principal use is in the alloy called German silver. The salts of nickel possess a beautiful green tint. The rare gem chryso-prase is colored with oxyd of nickel.

BISMUTH is a reddish-white metal. It is known

chiefly as an oxyd, in which form it is much prized as a cosmetic by those whose fading charms necessitate the use of pearl-powder. This should not be indulged in by ladies intending to visit chemical laboratories, or lectures, as a few bubbles of HS escaping into the air will change the snow-white complexion into a most suggestive black.

ANTIMONY was discovered by Basil Valentine, a monk of Germany, in the fifteenth century. It is said, that to test its properties, he first fed it to some hogs kept at the convent, and found that they thrived upon it. He then tried it upon his fellow-monks, but perceiving that they died in consequence, he forthwith named the new metal, in honor of this fact, *anti-moine* (anti-monk), whence our term *antimony* is derived.

Antimony is found as SbO_3 . It is a brittle bluish-white metal, with a beautiful laminated crystalline structure. It is used simply as an alloy for type-metal, Britannia-ware, etc. Its test is HS, which throws down a brilliant orange-colored precipitate. Example: Melt a small fragment before the blow-pipe, and throw the melted globule upon an inclined plane. It will instantly dart off in minute spheres, each leaving behind a long trail of smoke.

(Page 149.) NITRATE OF SILVER is much used in photography. An account of the processes pursued in this art may be interesting to some. The daguerreotype is named from M. Daguerre, the dis-

coverer, who received a pension of 6,000 francs per year from the French government. A plate of copper, plated on one side with silver, is exposed to the vapor of iodine until a compound of iodide of silver is formed upon the surface. This is extremely sensitive to the light, and for this reason the process is always conducted in a dark closet. The plate is then quickly carried, carefully covered, to the camera, and placed in the focus, where the rays of light from the person whose "picture is being taken" fall directly upon it. These rays decompose the iodide of silver, setting free the iodine. The amount of this change is directly proportional to the number of rays that are reflected from different parts of the person to form the image in the camera. A white garment reflects all the light that falls upon it, so that part of the plate corresponding will be very much changed. A black garment reflects no light, so that part will not be changed at all. The different colors and shades reflect varying proportions of light, and so influence the plate correspondingly. When the plate is taken out of the camera, it is carefully covered again and carried quickly into the dark closet. No change can be detected by the eye; but now expose it to the vapor of mercury, and wherever the silver has been freed from the iodine, the Hg combines with it, forming a whitish amalgam. The picture thus evoked comes forth nearly perfect in its lights and shades, but the whole side

of the plate is covered with the iodide of silver, which would blacken if we should carry it out into the light. This must, therefore, be removed, so we wash the plate with *hyposulphite* of soda ($\text{NaO}.\text{SO}_2$). This dissolves the iodide of silver, except where it has been fixed by the mercury, and our picture needs only washing and a little paint on the lips and cheeks to be finished. If, instead of iodine, we had used bromine, the bromide of silver thus formed would have been much more sensitive to the light, and the picture could have been taken much quicker.

PHOTOGRAPHY (light-drawing) is founded essentially upon the same principles as daguerreotyping. The process varies so much with different operators that only the general outlines can be given. The details depend upon the quickness, exactness, and skill of the artist so much, that the same materials in different galleries produce vastly different photographs. So much skill has been attained in this art, that instantaneous views are now taken by Anthony & Co., of New York. In their gallery the camera tube is closed by a slide which is drawn to its place by a heavy weight. The camera is "focused," for instance, upon a regiment of soldiers moving up Broadway, and the tube opens just as they are raising their feet for a step: before they place them on the ground the slide falls and the picture is taken—they are photographed all standing on one foot, and with the other in the air. The process is as follows: The glass plate is (1) thoroughly cleansed; (2) a small

quantity of iodized collodion * is poured upon it, which covers the glass with a thin transparent film, when (3) it is put in the "nitrate of silver bath," † where the salt of silver in the bath is absorbed by the collodion film and changed to iodide of silver. The plate is now ready for the picture. After the sitting the plate is (4) taken, carefully protected from the light, to the operator's room. Here the picture is (5) *developed* by a solution of protosulphate of iron, with a little acetic acid added. (6) It is washed thoroughly; (7) it is *fixed* with a solution of hyposulphite of soda; (8) it is washed and dried, and (9) coated with amber varnish to preserve the film from accidental injury. This completes the "*negative*." From this the pictures are (1) "*printed*" by placing the negative upon a sheet of prepared paper, ‡ and exposing it to the sun's rays. The lights and shades are now reversed, and when the colors are sufficiently deepened the picture is (2) *washed*, (3) *toned* in the "toning-bath," which contains chloride of gold, and imparts the delicate color to the photograph, (4) *washed*, (5) *fixed*, by

* Iodized collodion is composed of gun-cotton dissolved in alcohol and ether, iodized with iodide of ammonium and bromide of cadmium.

† The nitrate of silver bath contains nitrate of silver, iodide of silver, and water.

‡ The paper is "sensitized" by immersing it in a solution of chloride of sodium, and then in one of nitrate of silver, thus filling the pores of the paper with the chloride of silver, which is extremely sensitive to light.

placing the paper in hyposulphite of soda, (6) *washed*, (7) *dried*, and (8) mounted on card-board, which completes the picture.

The process of reducing silver ores at the West differs from the Mexican method given in the text. The powdered and roasted AgS is placed with Hg in iron pans, 5 feet in diameter and 2 feet deep. Here it is kept heated by steam to 180° and agitated by revolving stirrers. The chloride is not roasted but is simply powdered and then worked in the pans for an hour with NaCl before adding the Hg .

ORGANIC CHEMISTRY.

A RADICAL is the base of a system of compounds. Example: Na forms, by union with O , the oxyd of sodium. This combines with HO , forming the hydrated oxyd of sodium, and this again with various acids. In this way a regular series of compounds is produced in which Na is the starting point—the root, as it were. Thus:

Na	Sodium.	
NaO	Oxyd of sodium.	•
NaO.HO	Hydrated oxyd of sodium.	
NaO.HO.SO_3 ...	Sulphate of the hydrated oxyd of sodium.	
NaO.HO.NO_5 ...	Nitrate of the hydrated oxyd of sodium.	

A COMPOUND RADICAL is a compound that resembles an element in all its chemical behavior, and can be oxydized and transferred from one compound to another, forming chlorides, salts, etc., in the same manner as a metal, like copper or iron. Example: In the destructive distillation of $\text{C}_1\text{H}_6\text{O}_2$ (alcohol)

and SO_3 , the acid takes out an atom of HO , leaving $\text{C}_4\text{H}_5\text{O}$ —common sulphuric ether. Now, by taking an atom of O from this, there remains a colorless gas, C_4H_5 , which has received the name Ethyl and the symbol Ae . This plays the part of an element, and being composed of two elements, is called a compound radical. It is the root of a series of compounds, thus :

Ae —Ethyl (the radical).....	C_4H_5 .
AeO —Oxyd of ethyl (ether).....	$\text{C}_4\text{H}_5\text{O}$.
AeO.HO —Hydrated oxyd of ethyl (alcohol).....	$\text{C}_4\text{H}_5\text{O.HO}$.
AeCl —Hydrochloric ether.....	$\text{C}_4\text{H}_5\text{Cl}$.
AeCy —Cyanide of ethyl.....	$\text{C}_4\text{H}_5\text{Cy}$.
AeO.NO_5 —Nitrate of the oxyd of ethyl (nitric ether)....	$\text{C}_4\text{H}_5\text{O.NO}_5$.

By this we see that ether is the oxyd of ethyl, and may be represented by the symbol AeO , while alcohol is the hydrated oxyd of ethyl, and may be represented by the corresponding symbol AeO.HO .

HOMOLOGOUS bodies are those which differ from each other by the constant addition of C_2H_2 , or its multiple. By the decomposition of common alcohol, we procure a series of alcohols, ethers, and acids, which differ from each other by constantly adding C_2H_2 to the preceding member of the group.

<i>Alcohols.</i>	<i>Acids.</i>	<i>Ethers.</i>
Methylic.... $\text{C}_2\text{H}_4\text{O}_2$	Formic..... $\text{C}_2\text{H}_2\text{O}_4$	Methylic.... $\text{C}_2\text{H}_5\text{O}$
Common.... $\text{C}_4\text{H}_8\text{O}_2$	Acetic $\text{C}_4\text{H}_4\text{O}_4$	Common ... $\text{C}_4\text{H}_5\text{O}$
Propylic $\text{C}_6\text{H}_8\text{O}_2$	Propionic ... $\text{C}_6\text{H}_6\text{O}_4$	$\text{C}_6\text{H}_7\text{O}$
Butylic $\text{C}_8\text{H}_{10}\text{O}_2$	Butylic $\text{C}_8\text{H}_8\text{O}_4$	Butylic $\text{C}_8\text{H}_9\text{O}$
Amylic..... $\text{C}_{10}\text{H}_{12}\text{O}_2$	Valeric..... $\text{C}_{10}\text{H}_{10}\text{O}_4$	Amylic $\text{C}_{10}\text{H}_{11}\text{O}$
$\text{C}_{12}\text{H}_{14}\text{O}_2$	Caproic..... $\text{C}_{12}\text{H}_{12}\text{O}_4$	$\text{C}_{12}\text{H}_{13}\text{O}$
$\text{C}_{14}\text{H}_{16}\text{O}_2$	Æenanthylic. $\text{C}_{14}\text{H}_{14}\text{O}_4$	$\text{C}_{14}\text{H}_{15}\text{O}$
Caprylic $\text{C}_{16}\text{H}_{18}\text{O}_2$	Caprylic $\text{C}_{16}\text{H}_{16}\text{O}_4$	Caprylic $\text{C}_{16}\text{H}_{17}\text{O}$

Many of these various substances are of no practical value as yet, and some, as seen above, are merely hypothetical, but will probably be separated as the others have been, while all will doubtless become of use in the arts. In the art of dyeing they have been utilized, and have revolutionized the entire system. There are other compound radicals—as C_2H_3 , called methyl, symbol Me—whose oxyds form ethers, and hydrated oxyds alcohols, as in the case of Ae.

KAKODYL is a combination of Me with arsenic—thus, $Me_2 As$ —and is a fearfully poisonous liquid. It takes fire spontaneously in the air, producing HO, CO_2 , and AsO_3 . It has been used for filling bombs, as a most destructive agent of war. The homologous series has been continued up to melissic acid ($C_{60}H_{60}O_4$), and melissic alcohol ($C_{60}H_{62}O_2$). The extremes differ much in their characteristics. Formic acid, which is found in red ants (*formica rufa*), is a fiery pungent acid that blisters the skin, while melissic acid is a solid fat. The compound radical, like any metal or acid, unites directly with Cl, I, H, Zn, S, and forms crystallized salts.

SUBSTITUTION AND REPLACEMENT.—This curious law is stated thus—that “one or more elements of a compound may be replaced by any other element or group of elements which are equivalent in their chemical relations, and the chemical constitution remain unchanged.” (*Silliman*.) For example: 1st. Ammonia (NH_3) may be written thus: $N \begin{smallmatrix} H \\ H \\ H \end{smallmatrix}$. Now we

can substitute for an atom of H a compound radical, as Ae (ethyl), and we have $N \begin{array}{c} C_4H_5 \\ | \\ H \end{array}$, an ethyl-ammonia; or, displace two atoms of H, and we have $N \begin{array}{c} C_4H_5 \\ | \\ C_4H_5 \\ | \\ H \end{array}$, a bi-ethyl ammonia; or, substituting three atoms of ethyl, we have $N \begin{array}{c} C_4H_5 \\ | \\ C_4H_5 \\ | \\ C_4H_5 \\ | \\ H \end{array}$, a tri-ethyl ammonia. These three ammonias are called methylamine, dimethylamine, and trimethylamine. They closely resemble ammonia, neutralize acids, precipitate the bases from salts, form white clouds with HCl, as in the test of ammonia, and form crystallizable salts; though they steadily rise in boiling point, ethylamine boiling at 54.4° , and trimethylamine at 195.8° . Other radicals yield other ammonias, similar to ammonia in odor and other properties.

2d. Acetic acid ($C_4H_4O_4$) may be written $c_4 \begin{array}{c} |H| \\ |H| \\ |H| \\ |H| \end{array} o_4$, and the four atoms of its H may be replaced in succession by three atoms of HCl (hydrochloric acid), and form $c_4 \begin{array}{c} |HCl| \\ |HCl| \\ |HCl| \\ |HCl| \end{array} o_4$, without at all changing the acid character, and modifying but slightly its properties. This new acid is called chlor-acetic, symbol $C_4(HCl)_3O_4$.

3d. The hydrogen of Ammonia may not only thus be replaced by a compound radical, as ethyle, amyle, etc., but even by two or more radicals, or by chlorine, bromine, iodine, zinc, etc. Thus, tartaric acid ($C_8H_6O_{12}$) may be written $c_8 \begin{array}{c} |H| \\ |H| \\ |H_4| \end{array} o_{12}$. Now, if we re-

place two of the atoms of H with two atoms of Zn, we have $c_8 \begin{vmatrix} \text{Zn} \\ \text{Zn} \\ \text{H}_4 \end{vmatrix} \text{O}_{12}$, or $\text{C}_5\text{H}_4\text{Zn}_2\text{O}_{12}$; or, they can be replaced by one atom of Zn and one of K—thus, $c_8 \begin{vmatrix} \text{Zn} \\ \text{K} \\ \text{H}_4 \end{vmatrix} \text{O}_{12}$, and the symbol will be $\text{C}_5\text{ZnKH}_4\text{O}_{12}$. These various changes indicate what a vast field lies open for discovery in organic chemistry, and the multiplicity of possible compounds. The difficulty of properly classifying them is at present insurmountable.

ALDEHYDE.—Alcohol ($\text{C}_4\text{H}_6\text{O}_2$) is changed into acetic acid ($\text{C}_4\text{H}_4\text{O}_4$) by taking up two atoms of O from the air to combine with two elements of its H, thus forming two molecules of HO. In this there is an intermediate step, during which the two atoms of H seem to have left the alcohol in their anxiety to combine with O, while the alcohol has not yet taken its O to form the acetic acid. This intermediate substance ($\text{C}_4\text{H}_4\text{O}_2$) is called aldehyde. It may be smelt by holding a red-hot coil of platinum wire in a goblet containing a few drops of alcohol.

This experiment, showing the formation of aldehyde from alcohol, may be very profitably followed by another, illustrating the change of alcohol into acetic acid. Place a little platinum black in a watch crystal, near a small cup of alcohol. Cover them both with a glass receiver, and set them in the sunlight. Soon a mist will gather, and tiny streams of the condensed vapor of acetic acid will collect and run down the sides of the glass. Fresh air must be occasionally admitted to oxydize the alcohol.

(Page 199.) The term Morphia is used by those who think the substance an alkali; Morphine, by those who deem it a neutral body.

OPIUM-EATING has become so prevalent in this country that a few remarks upon it may not be unprofitable. The effect is principally upon the nervous system. A delicious reverie steals over the senses. Every avenue of sensation is thrilled with ecstatic enjoyment. The delirious dream becomes a vivid reality. Riches pour in abundantly, and the happy possessor revels in costly mansions with elegant appointments; he wanders in gardens of tropical luxuriance and gorgeousness, where birds of the rarest plumage sport in the branches, music trembles in the air, and perfumes steal the senses. History, poetry, science, art—all the treasures of knowledge are his, and the soul expands to utter the most brilliant thoughts. The grandest schemes present themselves and prompt to the pursuit of most impossible results. Every sense is satisfied, and the whole man is at perfect peace. But, with the effect of the drug, the dream passes off, and then there comes a peculiar longing, an insatiable craving, which demands a repetition of the fascinating stimulus. In the course of time the amount necessary to produce the desired effect becomes increased, until at last, in some cases, an ounce of laudanum, or ninety grains of the acetate of morphia have been consumed daily. At the first it seems only a gratification of a harmless desire, but insensibly, as

the habit becomes fixed, it develops an ungovernable passion. Step by step the unsuspecting victim is led on, until at last some vain effort at release reveals to him the chains by which he is fast bound to a fascinating but fearful practice. Too often he finds it already too late. The subtle alkaloid has worked its way into the tissues and coatings of his entire internal organism. At first, while combining with the nerves, it set free a vast amount of vitality and force, but now it has satisfied itself. Already the whole system is impregnated with it, and no additional dose produces a thrill even of the delicious rapture for which the drug was once so eagerly sought. If he continues its use, a CERTAIN, FEARFUL, AGONIZING DEATH AWAITS HIM. If, resolutely, he summons his already enfeebled will, and commences the conflict, an agony of endurance, which defies all description, is before him. The whole body must be reorganized, and, atom by atom, the life-energy of the man drag out of the flesh and blood the corrosive poison. For weeks and months he endures the terrible torture, racked by intensest agony in every nerve and fibre, with visions of horror filling the mind. At last, the constitution conquers or the man dies. Yet this fearful struggle is better than apathy, for the victim of this habit moves on directly to one fate—the opium-eater's grave.

This frightful but “o’er true” picture of the opium-

eater's fate should deter all persons from thoughtlessly using paregoric, laudanum, morphine, or opium, in any form, lest they, too, may come also to such a doom. In almost every case it is taken first as a sedative from pain or fatiguing labor, with no thought of becoming addicted to its use. But so insinuating is it that the victim forms the habit ere he is aware, and only knows he is a slave when for some reason he attempts to cease the customary dose and finds himself bound to a bitter servitude.

CIRCULATION OF MATTER.—The truth that matter passes from the animal back to the vegetable, and from the vegetable to the animal kingdom again, received a curious illustration not long since, as stated in the Hartford Press.* For the purpose of erecting a suitable monument in memory of Roger Williams, the founder of Rhode Island, his private burying-ground was searched for the graves of himself and wife. It was found that everything had passed into oblivion. The shape of the coffins could only be traced by a black line of carbonaceous matter. The rusted hinges and nails, and a round wooden knot, alone remained in one grave; while a single lock of braided hair was found in the other. Near the graves stood an apple-tree. This had sent down two main roots into the very presence of the confined

* The author has in his possession a letter, from a gentleman who was present at the opening of this grave, attesting the truth of this singular statement.

dead. The larger root, pushing its way to the precise spot occupied by the skull of Roger Williams, had made a turn as if passing around it, and followed the direction of the backbone to the hips. Here it divided into two branches, sending one along each leg to the heel, when both turned upward to the toes. One of these roots formed a slight crook at the knee, which made the whole bear a striking resemblance to the human form. There were the graves, but their occupants had disappeared; the bones even had vanished. There stood the thief—the guilty apple-tree—caught in the very act of robbery. The spoliation was complete. The organic matter—the flesh, the bones, of Roger Williams—had passed into an apple-tree. The elements had been absorbed by the roots, transmuted into woody fibre, which could now be burned as fuel, or carved into ornaments; had bloomed into fragrant blossoms, which had delighted the eye of passers-by, and scattered the sweetest perfume of spring; more than that—had been converted into luscious fruit, which, from year to year, had been gathered and eaten. How pertinent, then, is the question, “Who ate Roger Williams?”

Shakespeare expresses the same chemical thought when he says :

“Imperious Cæsar, dead and turned to clay,
Might stop a hole to keep the wind away.
Oh! that the earth which kept the world in awe
Should patch a wall to expel the winter’s flaw!”

Or, again, when he makes Ariel sing :

“ Full fathom five thy father lies :

Of his bones are coral made ;

Those are pearls that were his eyes ;

Nothing of him that doth fade

But doth suffer a sea change

Into something rich and strange.”

THE NEW NOMENCLATURE.

WITHIN the brief limits of this chapter it is proposed to state only the main points of distinction between what is termed the OLD and the NEW NOMENCLATURE. In this work we have used the former, because it is employed exclusively in trade and most American chemical works, and a knowledge of it is therefore indispensable even to those who may prefer the latter.

CLASSIFICATION OF THE ELEMENTS.—Certain elements are able to combine with or to displace only *one* atom of H. Examples, HCl . $\text{H}_2\text{O} + \text{K} = \text{HKO} + \text{H}$. Some can combine with or displace *two* atoms of H. Examples, H_2O . H_2S . $\text{H}_2\text{O} + \text{Ba} = \text{BaO} + 2\text{H}$. Thence arises a division of the elements into four classes according to their “atom fixing power,” *i. e.*, their ability of combining with or displacing 1, 2, 3, or 4 atoms of H.

1. *A monatomic element, or monad*, is equivalent in combination to *one* atom of H.

2. *A diatomic element, or dyad*, is equivalent in combination to *two* atoms of H.

3. *A triatomic element, or triad*, is equivalent in combination to *three* atoms of H.

4. *A tetraatomic element, or tetrad*, is equivalent in combination to *four* atoms of H.

CLASSIFICATION OF COMPOUND RADICALS. (See page 252 *et seq.*) These classifications may be applied also to those groups of elements which play the part of elements in the formation of compounds. Water may be written $\begin{array}{c} \text{H} \\ \text{H} \end{array} \left| \text{O} \right.$; Nitric Acid, $\begin{array}{c} \text{H} \\ \text{NO}_2 \end{array} \left| \text{O} \right.$, which is only water with one atom of H replaced by the monad radical NO_2 . Nitric Pentoxyd (N_2O_5) is water with the second atom of H replaced by the same radical; thus, $\begin{array}{c} \text{NO}_2 \\ \text{NO}_2 \end{array} \left| \text{O} \right.$. Sulphuric Acid may be considered a dyad radical SO_2 , and Phosphoric Acid a triad radical PO .

The following list contains the elements as classified by Miller:

MONADS.

<i>Element.</i>	<i>Symbol.</i>	<i>Atomic Weight.</i>	<i>Element.</i>	<i>Symbol.</i>	<i>Atomic Wt</i>
Bromine.....	Br.....	80.	Lithium.....	L.....	7.
Chlorine.....	Cl.....	35.5	Potassium.....	K.....	39.
Cæsium.....	Cs.....	133.	Rubidium.....	Rb.....	85.
Fluorine.....	F.....	19.	Silver.....	Ag.....	108.
Hydrogen.....	H.....	1.	Sodium.....	Na.....	23.
Iodine.....	I.....	127.	Thallium.....	Tl.....	204.

DYADS.

Barium.....	Ba.....	137.	Manganese.....	Mn.....	55.
Cadmium.....	Cd.....	112.	Mercury.....	Hg..	200.
Calcium.....	Ca.....	40.	Nickel.....	Ni.....	59.
Cerium.....	Ce.....	92.	Oxygen.....	O.....	16.
Chromium.....	Cr.....	52.5	Palladium.....	Pd.....	106.5
Cobalt.....	Co.....	59.	Selenium.....	Se.....	79.5
Copper.....	Cu.....	63.5	Strontium.....	Sr..	87.5
Didymium.....	D.....	96.	Sulphur.....	S.....	32.
Glucinum.....	G.....	9.3	Tellurium.....	Te.....	129.
Iron.....	Fe.....	56.	Thorium.....	Th.....	119.
Lanthanum.....	La.....	92.	Uranium.....	U.....	120.
Lead.....	Pb.....	207.	Zinc.....	Zn.....	65.5
Magnesium.....	Mg.....	24.3			

TRIADS.

Aluminum.....	Al.....	27.5	Gold.....	Au.....	196.6
Antimony.....	Sb.....	122.	Nitrogen.....	N.....	14.
Arsenicum.....	As.....	75.	Phosphorus.....	P.....	31.
Bismuth.....	Bi.....	210.	Rhodium.....	Ro.....	104.3
Boron.....	B.....	10.9			

TETRADES.

Carbon.....	C.....	12.	Tantalum.....	Ta.....	138.
Niobium.....	Nb.....	97.5	Tin.....	Su.....	118.
Platinum.....	Pt.....	197.	Tantanium.....	Ti.....	50.
Silicon.....	Si.....	28.	Zirconium.....	Zr.....	89.5

In this table it will be noticed that a large number of the atomic weights are double those in the old system. The other *slight* variations are those only which are common to the various chemical authorities. To indicate this doubling, the Dyads, Tetrads, and the element Aluminum are sometimes distinguished by barred symbols; thus, $\bar{\text{O}}$, $\bar{\text{O}}$, &c.

NOTATION.—The symbol for water is H_2O . The ox-acids contain H_2O , the symbol for which is written be-

fore that of the acid itself; thus, $\text{H}_2\text{O} \cdot \text{SO}_3$ (Sulphuric Acid); $\text{H}_2\text{O} \cdot \text{N}_2\text{O}_5$ (Nitric Acid). They are considered merely combinations of O with the radical H, which is therefore written first; thus, H_2SO_4 ; $\text{H}_2\text{N}_2\text{O}_6 = 2\text{HNO}_3$. The acids are properly hydrogen salts, that element being universally admitted to be a metal, in which H plays the part of the base. In writing the symbol of a base the H_2O which is contained in combination is written *after* instead of before, as in the case of an acid. These also are really salts in which H_2O plays the part of the acid. The notation of the mixed salts differs somewhat from the old notation. Thus $\text{KAl}(\text{SO}_4)_2$ is the double sulphate of Alumina and Potash; $\text{Al}_2(\text{SO}_4)_2\text{O}_2$ is Aluminic-sulphate-dioxyd; $\text{Fe}_2(\text{SO}_4)_2\text{O}$ is the Ferric-disulphate-oxyd.

NUMERATION.—In reading the symbols of Binary Compounds, the electro-negative element takes the termination *ide*. This forms what may be termed the *generic* name; thus we have Iodides, Chlorides, &c. There is also a *specific* name derived from the electro-positive element by the use of the termination *ic*; thus Mercuric, Potassic, Argentic, &c. Examples: KCl may be read Chloride of Potassium and also Potassic Chloride; AgFl forms Argentic Fluoride and Fluoride of Silver; HgCy , Cyanide of Mercury and Mercuric Cyanide.

Following the analogy of the common names Sulphate of Copper, Nitrate of Silver, &c., the salts of the Alkaline and Alkaline earth metals are named Carbonate of Sodium, Sulphate of Potassium, &c. The principle of specific and generic names is applied to them also, so that they are frequently styled Sodie Carbonate, Potassic Sulphate. Thus CuSO_4 is either Sulphate of Copper or Cupric Sulphate; CaCO_3 is Carbonate of Calcium or Calcic Carbonate.

The terminations *ous* and *ic* are applied to oxyds and salts of the metals as well as to the acids. Thus Hg_2O is Mercurous Oxyd; HgO is Mercuric Oxyd; Hg_2Cl_2 is Mercurous Chloride (calomel); HgCl_2 is Mercuric Chloride (corrosive sublimate); FeO is Ferrous Oxyd; Fe_2O_3 is Ferric Oxyd (sesquioxyd of iron); Cu_2Cl_2 is Cuprous Chloride; CuCl_2 is Cupric Chloride.

Oxacids which do not contain H_2O are termed *Anhydrides*. In Organic Chemistry the old formula can be changed to the new, in general, by taking half the number of atoms of C and O; thus, Alcohol $= C_4H_8O_1$ (old) $= C_2H_6O$ (new).

TABLE OF THE PRINCIPAL COMPOUNDS.—The following are the names and symbols of the principal compounds named in this work:

ACIDS.

Sulphuric Acid.	<i>Dihydric Sulphate</i>	H_2SO_4
Nitric Acid... ..	<i>Hydric Nitrate</i>	HNO_3
Chloric Acid	<i>Hydric Chlorate</i>	$HClO_3$
Phosphoric Acid.....	<i>Phosphoric Anhydride</i>	P_2O_5
Carbonic Acid.....	<i>Carbonic Dioxide</i>	CO_2
Hydrochloric Acid	<i>Hydric Chloride</i>	HCl
Hydrosulphuric Acid.	<i>Dihydric Sulphide</i>	H_2S
Sulphurous Acid.....	<i>Sulphuric Dioxide</i>	SO_2
Nitrous Acid	<i>Nitric Trioxide</i>	N_2O_3
Chromic Acid.....	<i>Chromic Anhydride</i>	CrO_3
Arsenious Acid.. ..	<i>Arsenious Anhydride</i>	As_2O_3
Silicic Acid.....	<i>Silicic Dioxide</i>	SiO_2
Boracic Acid.....	<i>Boracic Trioxide</i>	B_2O_3
Bisulphide of Carbon	<i>Sulpho-Carbonic Acid</i>	CS_2

THE ALKALIES.

(Oxyds of the Alkali-metals, K, Cs, Na, Rb and L.)

Ammonia.....	H_3N	Soda.....	Na_2O
Potassa.....	HKO		

THE ALKALINE EARTHS.

(Oxyds of the metals of the Alkaline Earths, Ba, Sr, and Ca.)

Lime	CaO	Baryta	BaO
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OXYDS.

Manganese Dioxide ..	MnO_2	Mercurous Oxyd....	Hg_2O
Ferrous Oxyd....	FeO	Mercuric Oxyd	HgO
Ferric Oxyd	Fe_2O_3	Alumina.....	Al_2O_3
Black Oxyd of Iron ..	Fe_3O_4	Nitrous Oxyd.....	N_2O
Red Lead.....	$2PbOPbO_2$	Nitric Oxyd.....	NO

SALTS.

Ammonium Sulphate	$2(NH_4)SO_4$	Ammonium Nitrate.	NH_4NO_3
Barium	" $BaSO_4$	Copper	" Cu_2NO_3
Calcium	" $CaSO_4$	Lead	" Pb_2NO_3
Copper	" $CuSO_4 + 5H_2O$..	Potassium	" KNO_3
Ferric	" Fe_2SO_4	Silver	" $AgNO_3$
Ferrous	" $FeSO_4 + 7H_2O$	Sodium	" $NaNO_3$

Lead Sulphate.	PbSO_4	Strontium Nitrate ..	SrNO_3
Magnesium "	$\text{MgSO}_4 + 7\text{H}_2\text{O}$	Calcium Phosphate. Ca_3PO_4	
Potassium "	K_2SO_4	Sodium "	HNa_2PO_4
Sodium "	$\text{Na}_2\text{SO}_4 + 10\text{H}_2\text{O}$	Sod. Superphosphate	H_2NaPO_4
Zinc "	$\text{ZnSO}_4 + 7\text{H}_2\text{O}$	Sodium Carbonate..	Na_2CO_3
		Sod. Bicarbonate ..	HNaCO_3
Cupric Sulphide.....	CuS	(Hydric Sodium Carb.)	
Ferrous "	FeS	Potass. Carbonate ..	K_2CO_3
Lead "	PbS	Potass. Bicarbonate.	HKCO_3
		(Hydric Potassium Carb.)	
Silver "	Ag_2S	Calcium Carbonate	CaCO_3
Mercuric "	HgS	Lead "	PbCO_3
Sodium Sulphite.....	$\text{Na}_2\text{SO}_3 + 7\text{H}_2\text{O}$	Magnesium "	MgCO_3
Sodium Nitrite	NaNO_2	Potassic Chlorate..	KClO_3
Sod. Hyposulphite... ..	$\text{Na}_2\text{S}_2\text{H}_2\text{O}_4 + 4\text{H}_2\text{O}$	Potassic Chloride..	KCl
Potass. Bichromate..	$\text{K}_2\text{O}_2\text{CrO}_3$	Calcium "	CaCl
Sodium Biborate	$\text{Na}_2\text{O}_2\text{B}_2\text{O}_3 + 10\text{H}_2\text{O}$	Ammonium "	NH_4Cl

ATOMICITY.—The prominent feature of this system is that the symbols of the elements represent, not *equivalents* but *atoms*. In the symbols the tendency is to give the *atomic* and not the *molecular* composition of the body; thus the symbol for Sulphate of Magnesium is $\text{MgH}_{14}\text{SO}_{11}$, which is the atomic expression; but as it is composed of 7 molecules of water, the molecular expression is $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$; H_2SO_4 is written $\text{H}_2\text{O} \cdot \text{SO}_3$. The former is sometimes termed the *unitary* and the latter the *dualistic* method.

REACTIONS.—Oxygen $2\text{KCO}_3 = 2\text{KCl} + 3\text{O}_2$.

Hydrogen $\text{H}_2\text{SO}_4 + \text{Zn} = \text{ZnSO}_4 + \text{H}_2$.

Carbonic Acid.. $\text{CaCO}_3 + 2\text{HCl} = \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$.

In the last instance the H_2 of the acid changes place with the Ca , and forms Carbonic Acid ($\text{H}_2\text{CO}_3 = \text{H}_2\text{O} \cdot \text{CO}_2$), which immediately breaks up into H_2O and CO_2 . The latter comes off with a brisk effervescence.

Sulp. of Potassium. $2\text{HKO} + \text{H}_2\text{SO}_4 = 2\text{H}_2\text{O} + \text{K}_2\text{SO}_4$.

Here the two atoms of K of the base and the two atoms of H in the acid have simply changed places. This is an instance of double decomposition or replacement, and is a sample of a large class.

Acid Sulp. Potassium. $\text{KNO}_3 + \text{H}_2\text{SO}_4 = \text{HNO}_3 + \text{HKS}_4$.

In this case only one atom of K and one of H have replaced each other.

QUESTIONS.

THE following questions are those which have been used by the Author as a daily review and examination of this study. The figures refer to the pages of the book. The symbols, names, and reactions given in parentheses are always those of the New Nomenclature. Thus, while using the Old, the pupil will insensibly acquire the New. Many "Practical Questions" are introduced throughout, in order to test the pupil's comprehension of the subject. Illustrations should always be given by the pupil, whenever practicable, without a special question.

INTRODUCTION.—Define Chemistry. Name and define its general divisions. Define an element. How many elements? Is it certain that all are now discovered? How are the elements classified? Define chemical affinity. How does it act?

10. Is it governed by laws? Is there any similarity between a compound and its elements? Illustrate the effect of heat on chemical action. Of light. Of solution. Define the chemical equivalent.

11. Is a compound always composed of the same elements? Give the four laws of the Atomic Theory. Give the principles on which the elements are named. How are the symbols formed?

12. How is more than one equivalent of an element indicated?

13. Define a binary compound. Which element is placed first in reading the symbol of a compound? In writing? What is the use of the terminations *-ide*? *-uret*? Define an Oxyd. Define the different compounds of O. How are binaries classified? Must an acid always be sour? Name one that is not (page 94). What are the tests? Name and define the two divisions of the acids. How does the termination indicate the strength?

14. What is the meaning of the prefix *per*?—*hypo*? How are the hydracids named? Define a base. An alkali. What is the difference between potassa and potassium? What is

the reciprocal influence of the alkalies and acids? Define a salt.* How is it named? What is the difference between an *-ate*, an *-ite*, and an *-ide* compound? Define a neutral.

15. What is a formula? What signs are used? Give the symbols of the principal acids (p. 265). Alkalies. Bases. Salts.

16. To what is the proportion of an element in any compound always equal? The weight of an element? State the proportion to be used in solving problems (p. 227).

NON-METALLIC SUBSTANCES.

OXYGEN.—Give the symbol and equivalent of oxygen. What is the meaning? What other element is an acid-former? Name the sources of O. Do these fractions indicate weight or volume? How is O prepared from chlorate of potash and black oxyd of manganese (potassic chlorate and manganese di-oxide)?

19. Give the reaction (p. 266). What becomes of the chloride of potassium (potassic chloride)? What is the use of the black oxyd of manganese? Define catalysis. Properties of O? What is oxydation? An oxyd? Show that O is a supporter of combustion. What compounds are formed in these illustrations?

22. Describe the destructive effects of the O in the air. What causes the decay of peaches? Why does not canned fruit decay? Describe the action of O on fuel. On a dead body. On impure water. On writing-ink. On red-hot iron. On damp knives and forks. Why is not a higher oxyd formed at the forge than in the pantry? How is river water purified on a sea-voyage?

24. By what means is the O carried through the system? What work does it perform in the body? Why is the blood in the arteries red and in the veins black? What common processes are included by the chemist under the term combustion? Why? Does fire differ from decay? Is heat always a product of oxydation? What is the source of this heat (p. 222)?

25-6. In what sense is the body a furnace? What is the fuel? Describe the process of starvation. Why do we eat more food in winter than in summer? Would a fat man endure starvation longer than a lean one? Show how O produces motion. What is the source of the power we thus exert

* Some include neutrals under the head of salts. In that case common salt is a true salt. They divide salts into two classes—the oxysalts, as given in the text, and the haloid salts (p. 86).

(p. 224)? Why do teamsters warm themselves by slapping their hands? Why does running cause panting? Why does one die when his breathing is stopped? Could a person commit suicide by holding his breath? Why do we need extra clothing when we sleep, even at midday, in the summer? How do hibernating animals illustrate this? How does a cold-blooded animal differ from a warm-blooded one? Show how O is constantly burning the body. Is there any part of our body that is permanent? Illustrate the rapidity of this change. Why does not the whole body burn out, like a candle?

27. Show the truth of the paradox—"We live only as we die." Why do we need food and sleep? Show how O acts as a scavenger in nature. Is this a useful provision?

28. What is the effect of undiluted O on a rabbit? On a human being? What would be the result, if the air were pure O? What objects would escape combustion?

29. What is ozone? Where is it seen? Preparation? Properties? Is it a valuable constituent of the air?

30-1. NITROGEN.—Symbol and equivalent? Why so called? Sources? Preparation?

32. Properties? Why does a person drown in water? Would a person die in pure N? What is the peculiarity of the nitrogen compounds? What causes flesh to decompose so much more easily than wood? Does the N we take in at each breath do us any direct good or harm? Where do we get N to make our flesh? What use do plants make of the N they breathe in through their leaves? Describe the conduct of N and O in our stoves.

33. Why does N come thus from plants, fires, and our lungs unchanged? State the main distinction between O and N. What is the office of the N in the air? Show that the proportion of O and N in the atmosphere gives us the golden mean.

34. Symbols and equivalents of nitrous oxyd (N_2O)? The common name? Preparation? Reaction ($NH_4NO_3 = N_2O + 2H_2O$)? Properties?

35. For what purpose has liquid nitrous oxyd been used? (Phil., p. 242.) What is the effect of nitrous oxyd on the human system? State its use in surgical operations. Explain.

36-7. Symbol and equivalent of nitric acid (HNO_3 , hydrogen nitrate)? Common name? Preparation? Reaction ($KNO_3 + H_2SO_4 = HNO_3 + HKSO_4$)? Explain its occasional presence in the atmosphere. Properties?

38. Has it been obtained as a solid? How does it rank in strength? What color does it give to wood? Uses? Explain its oxydizing action. What is aqua regia? Describe the pro-

cess of etching. Describe the action of nitric acid on tin. On copper. What compounds are formed? What fumes pass off? Show that the change from nitric oxyd to nitrous acid produces the red color. Why is ammonia or hartshorn so called? What is the aqua ammonia of the shops?

40. Should care be used in opening a bottle of strong NH_3 in a warm room? Is it safe to touch or taste undiluted NH_3 ? Test? Prove that it is an alkali. Antidote? What causes the pungent odor of compost? With what are smelling-bottles filled? Reaction $(\text{CaO} + 2\text{NH}_4\text{HCl} = \text{CaCl}_2 + 2\text{NH}_3 + \text{H}_2\text{O})$.

41. Define the nascent state. Symbol and equivalent of sal-ammoniac? Preparation? Does the salt reveal the presence of NH_3 ? How can the gas be set free? Uses, especially in soldering?

HYDROGEN.—Symbol and equivalent? Meaning of the name? Preparation? Reaction (p. 266)?

43. What compound is formed (zinc sulphate)? Properties? Is H a metal (p. 238)? The size of its atoms? Its levity? Will it destroy life? Effect on the voice? Use in filling balloons?

44. What is the product of the combustion of H? What is the philosopher's lamp (page 237)? Dobereiner's lamp? What are the mixed gases? Why do we take five parts of air and only one of O? What is the cause of the report? Will the gases combine, if mixed.

45-6. What compound is formed? What becomes of the HO? What is the action of platinum sponge on a jet of H? How are hydrogen tones produced? Explain.

47. **WATER.**—What is the freezing and the boiling point of water? How is the composition of water proved? Why does the blacksmith sprinkle water on his forge fire? Why do we moisten our coal cinders (p. 239)?

48. What injury may a small quantity of HO do, if thrown on a fire? Can HO, then, be burned? Show that electrical force is latent in water. Illustrate the abundance of HO in the animal world. Vegetable world? Mineral world?

50. Why will blue vitriol (copper sulphate) lose its color if heated? What is "burnt alum"? Water of crystallization? Show the adaptation of HO as a solvent. What water is the purest? Why does rain-water taste so insipid? What is hard water? Soft water?

51. Why does the hardness of water vary in different places? What minerals are most common in water? What is the "fur" in a tea-kettle? Why does soap curdle in hard water? What causes the variety of minerals in the ocean? Is the quantity increasing? Is there not a compensation in

the growth of sea-plants, fish, &c., which are washed back on the land? Since "all the rivers flow to the sea," why is it not full? What is the cause of the tonic influence of the sea-breeze? How could Salt Lake be freshened? What is the use of the air in HO ? Tell how fish breathe. When fish are taken out of the water, they are brought into a more abundant atmosphere, why then do they die? Do all fish die when brought on land?

52. Why does the air in water contain so much O ? Why is boiled water so insipid? Give some of the paradoxes of water.

53. Name the various uses of water. (Phil., p. 255.)

CARBON.—Symbol and Equivalent? ($\text{C}=12$.) Illustrate the abundance of C . Is it more characteristic of the vegetable or the mineral kingdom? What are its three forms? Proof of these allotropic states? What is an allotropic condition?

55. What is the diamond? Properties? Origin? Has it ever been made artificially? (p. 239.) What is a carat? How is the diamond ground?

56. Describe the three modes of cutting. What gives the diamond its value? Common name for graphite? Origin? Uses? Describe the process of making a lead-pencil. What causes the difference between a No. 1 and No. 4 pencil?

57. Why does it dull a knife to sharpen a pencil? What is a black-lead crucible? What is British Lustre? Gas carbon? How is charcoal made?

58. What is the chemical change? Illustrate the durability of charcoal. Its property of absorbing gases. Its preservative effects. Its filtering properties. (Phil., p. 41.)

59. What do you mean by the deoxydizing or reducing action of C ? Application to the arts? What is soot? What causes the burning of chimneys? Does this occur oftener when wood or when coal is used as fuel?

60. How is lampblack made? Uses? Fitness for printing? What can you say about ancient MSS? How is bone-black made? Uses? How is sugar refined?

61. Describe the formation of coal. Difference between bituminous and anthracite coal? Why is coal found in layers with slate, etc. between? Why is the coal hidden in the earth? Where was the C now in coal prior to the carboniferous era? Must not the air then have been rich in plant-food? (p. 84.)

62. What proof have we that coal is of vegetable origin? What is coke? Uses? Describe the formation of peat. Uses?

63. What is muck? Use? Name some of the diverse properties and uses of C .

CARBONIC ACID.—Symbol and equivalent (Carbonic Anhy-

dride)? Sources? How it is constantly formed? Preparation? Reaction (p. 266)?

66. Test? What causes the thin pellicle on lime-water? What does this show? Prove that we exhale CO_2 . Why will lime added to hard water often soften it? Properties? How would you show that CO_2 has an acid taste? Prove that it is heavier than air. A non-supporter of combustion.

67. What can you say of its poisonous properties? What test should be employed before descending into a deep well or an old cellar? How can you remove the foul air? Tell about the Grotto del Cane.

68. The Upas-tree? Is CO_2 directly poisonous? What is choke-damp? Fire-damp? Which is more dreaded? Has CO_2 been used for extinguishing fires?

69. Tell about the absorption of CO_2 by HO . What is soda-water? Why does wine sparkle and beer foam? Why does the cork often fly out of catsup bottles? How is CO_2 liquefied? Why does the liquid acid solidify when exposed to the air? What principle in Philosophy does this illustrate?

70. How low a degree of cold has been produced in this manner? Describe the need of ventilation (p. 239). Is a single opening sufficient to ventilate a room? What practical application do you make of this subject? Why will a division in an opening start two currents, as in the experiment? How is the air expired from our lungs made useful?

71. Symbol and equivalent of Carbonic Oxyd? Properties? When do we often see it? What causes the unpleasant odor of coal-gas? Symbol and equivalent of Light Carburetted Hydrogen? Properties? How is it formed? Name the places where it is found in great quantities.

72. Symbol and equivalent of Heavy Carburetted Hydrogen? Properties? What two gases mainly compose illuminating gas? Which is the more valuable? Describe the manufacture. What causes the odor? What produces the sparkling often seen in the flame? *Ans.* The lime taken up in minute particles. Why is the jet flat? When we turn the gas very low, or the supply is insufficient, why is the flame blue? Symbol and equivalent of Cyanogen (CN)? Preparation? What are its compounds called? What is the red prussiate of potash? How is blue ink made? (p. 241.)

Symbol of hydrocyanic acid? (HCN .) Common name? Where found? Antidote? What are the fulminates? How are gun-caps made?

COMBUSTION.—Define. What is a combustible? A supporter of combustion? (The difference between these two is

nicely shown in the experiment with H on p. 44.) A burnt body? *Ans.* A body which has combined with O. Ex. : a stone, water. Upon what does the amount of heat produced by combustion depend? The intensity? Why does H give out more heat in burning than C? Why do we need a draught to a stove? Why does blowing on a fire kindle it, and on a lighted candle extinguish it? Does combustion, in its chemical sense, commence before the fuel catches fire? Why do we use "kindlings" in starting a fire?

75. Why can we not ignite hard coal with a match? Why can we light pitch-pine so easily? Why will an excess of coal put out a fire? Why is stirring a wood fire beneficial, but a coal fire injurious? What are hydro-carbons? Why will not stones burn, as well as wood or coal? What are the ordinary products of combustion? What causes the dripping of stove-pipes? What are the ashes? Why does fresh fuel produce a flame? Why will not hemlock make good coals? Is there a gain or a loss of weight by combustion? Show how wisely C is adapted for a fuel. What would be the effect if CO_2 were not a gas?

76. Define flame. Describe the burning of a candle. Show that flame is hollow.

77. What causes the light? Is there any nice adaptation of chemical affinities exhibited here? Why is the flame blue at the bottom? Products of combustion? Tests? Why does not the wick burn? Why does it turn black? What causes the coal at the end of the wick? To what is the tapering form due? Why does snuffing brighten the light? Why does a draft of air, or a sudden movement of the candle, cause a deposit of soot? Which is the hottest part of a flame? Why is the flame of a candle or lamp red, or yellow? *Ans.* Because the heat is not sufficient to cause the carbon to emit all the rays of the spectrum.

78. Use of plaited wicks? Object of a chimney to a lamp? A flat wick? Advantage of an Argand lamp? What is the film which gathers on the chimney when the lamp is first lighted? Why does this soon disappear? Why do tar, spirits of turpentine, etc., burn with much smoke? Why does alcohol give much heat and no smoke? Describe Davy's safety-lamp. Illustrate this by a wire gauze over the flame of a candle.

79. Why does blowing on a light put it out? Do we not sometimes drive the blaze off from the wick? Why does water extinguish a fire? If a person's clothes take fire, how should we put out the fire? Ought we to open the doors and windows

of a burning building? Give illustrations of spontaneous combustion.

80. Describe the compound blow-pipe. Cause of the intense heat. Why is there no light?

81. Describe the calcium light. By what other names is it known? Cause of the intense light. Why does not the lime burn? Describe the common blow-pipe. The reducing flame. The oxydizing flame. What causes the difference in the properties? *Ans.* There is a scarcity of O in one and an excess in the other. Why is the blow-pipe flame blue? Why is the light of a gas-jet rendered blue if the wind blow upon it? Is the light then as intense? Why not?

THE ATMOSPHERE.—Name the constituents. Proportion. State the comparison.

83. What is the law of diffusion? What effect does this have on the air? Is the air a chemical compound? Has each constituent a special use? Name the uses of O.

84. Carbonic acid. Explain the chemical change which takes place in the leaf. What force separates the C from the O? (p. 224.) What relation exists between animals and plants? Which gathers and which spends the solar force? Which performs the office of reduction? Which that of oxydation? Are plants in a room healthy? What do you say of the exact balance kept between the wants of animals and plants?

85. What is the use of the watery vapor in the air? Which of the constituents are permanent? Is this a wise provision? Why ought the vapor to be easily changed to the liquid form?

86. What effect does this permanence have on sound?

THE HALOIDS.—Name them. Symbols and equivalents. What compounds do they form? Why is chlorine so called? Source? Preparation? Reaction (p. 242), $(\text{MnO}_2 + 2\text{NaCl} + 3\text{H}_2\text{SO}_4 = \text{MnSO}_4 + 2\text{NaHSO}_4 + 2\text{H}_2\text{O} + \text{Cl}_2)$.

87. Properties? What action does it have on phosphorus, arsenic, etc.? Why does a solution of the gas soon become acid? What is its action on organic bodies? On turpentine? On printers' ink?

88. Symbol and equivalent of hydrochloric acid? Common name? Preparation? Reaction $(\text{NaCl} + \text{H}_2\text{SO}_4 = \text{NaHSO}_4 + \text{HCl})$. Properties? What is muriatic acid? What are its compounds termed? Tests? What is nitro-muriatic acid? Symbol and equivalent of chloride of lime (p. 242)?

89. Uses? Describe the old process of bleaching. The modern method.

90. How may stains be removed from uncolored cloth?

Describe the action of Cl as a disinfectant. Tell what you can about bromine. What is the peculiarity of fluorine?

91-2. Source? What acid does it form? For what is this acid noted? Describe the process of etching with HFl. Why is not HFl kept in ordinary bottles? Is it dangerous to use? Why is iodine so called? Preparation? Properties? For what are its compounds noted? How may its stains be removed? Test? Use in medicine?

BORON.—Symbol and equivalent? Source? Describe the scene in Tuscany where it is found. Process of manufacture?

93-4. Symbol and equivalent of borax? Uses in soldering, and in softening hard water?

SILICON.—Symbol and equivalent? Source? Common names? What gems does it form? What is sand? Properties? Why is it called an acid? Is silica soluble in HO? How does it get into plants? In what plants is it found? Explain the process of petrification.

SULPHUR.—Symbol and equivalent? Sources? What is the principle of hair-dyes? Why do eggs tarnish silver spoons? What is the difference between brimstone and flowers of sulphur? Properties? Solvent? Three allotropic forms? Describe the amorphous state.

96. Symbol and equivalent of sulphurous acid (sulphurous anhydride)? Where is it familiar? What are its compounds called? Uses in bleaching? Why are new flannels liable to turn yellow when washed? Symbol and equivalent of sulphuric acid (H_2SO_4)? Common name? State its importance. What are its compounds called?

97. Illustrate the making of SO_3 (H_2SO_4). Describe its manufacture. Reaction?

98. Properties? What especial property? Illustrate.

99. Is it safe to mix oil of vitriol and water in a glass bottle? Its strength? Color of its stain on cloth? How removed? On wood? Cause of this action? Test? What causes the milky look when HO and SO_3 are mixed? What is Nordhausen acid? Symbol and equivalent of hydrosulphuric acid—sulphide of hydrogen? Where is it found?

100. Preparation? Reaction? Properties? Use? Color of these precipitates? Test? Symbol and equivalent of bisulphide of carbon? Preparation? Properties? Uses? How does it illustrate the force of chemical affinity?

PHOSPHORUS.—Symbol and equivalent? Why so called? Source? In what parts of the body, and in what forms, is it found? Preparation?

102. Properties? Caution to be observed? Is phosphorus

poisonous? What is the product of its combustion? (P_2O_5). Oxydation? What are the compounds of PO_5 called? Describe the amorphous form of phosphorus. The process of making matches. Reaction in burning. What compounds are formed?

103. Will not the wood ignite from the burning phosphorus? Tell what you can about phosphorescence. Its cause? Symbol and equivalent of phosphide of hydrogen? Source? Where is it found?

104. Preparation (p. 243)? For what noted?

THE METALS.

POTASSIUM.—Symbol and equivalent? History of its discovery? Source? How do we get our supply?

105. Properties? How must it be kept? Reaction when thrown on HO (H_2O)? Symbol and equivalent of potash? Properties? Its feel? Its affinity for HO and CO_2 ? Is it poisonous? Test? Uses? Symbol and equivalent of carbonate of potash? Common name?

106-7. Preparation? What part of the tree furnishes the most potash? What is the derivation of the word? Symbol and equivalent of saleratus? Preparation? Symbol and equivalent of nitrate of potash (potassium nitrate, KNO_3)? Common names? Where is it found? How is it prepared artificially? How much hot water would be required to dissolve a pound of this salt? Properties? Uses? What is the composition of gunpowder? Cause of its explosive force? The bad odor of burnt powder? Composition of fire-works.

SODIUM.—Symbol and equivalent? Source? What proportion does it form of common salt? What element does it resemble? Reaction when thrown on water? What compound is formed? Why will it burst into a blaze on hot water?

108. Test? Symbol and equivalent of common salt? What use does it subserve in the body? Is salt abundant?

109. Describe the manufacture. What is solar salt? What causes the difference between table-salt and coarse salt? Describe the "hopper-shape" crystal.

110. Is it best to heat the water for dissolving salt? What is a saturated solution? Symbol and equivalent of sulphate of soda (soda sulphate, Na_2SO_4)? Common name? Preparation? Reaction? What curious property has this salt? Is this crystallization a cooling or a heating process? Why will the dropping in of a crystal cause solidification? Symbol and equivalent of carbonate of soda (soda carbonate, Na_2CO_3)? Common names?

111. Describe its manufacture (p. 232). Why will it soften

hard water? Uses? Symbol and equivalent of bicarbonate of soda (hydrogen sodium carbonate, HNaCO_3)? Common name? Preparation? Symbol and equivalent of common window-glass? Antiquity of glass? Pliny's story of its origin? What is said of its value in the 12th century?

112. Preparation? Essential ingredients? Effect of CaO ? As ? Pb ? Fe_2O_3 ? BO_3 ? From what is Bohemian glass made? Why is flint-glass so called? How is glass colored?

113. How is glass annealed? Is this process necessary? What is the Prince Rupert's drop (Phil., p. 40)? How are Venetian balls made? Tubes? Beads? Why do the figures in a paper weight always look so large?

114. Give the theory of Ammonium. How is the symbol NH_4O obtained? What is a radical (p. 252)?

CALCIUM.—Symbol and equivalent? Source? In what part of the body is it found? In what form do we commonly see it? Symbol and equivalent of lime (calcium oxide)? Preparation? Describe a lime-kiln (p. 244). Properties? Test? What is the difference between "water-slacked" and "air-slacked" lime? Uses? What is whitewash? Concrete? Hard-finish? Calcimining? Why will oyster-shells on the grate of coal-stoves prevent the formation of "clinkers"? Why are oyster-shells burned in order to make lime-water?

114. Theory of the hardening of mortar? Why are newly-plastered walls so damp? Will mortar harden if protected from the air? Why? What is water-lime? Action of lime on the soil? Will it not lose its beneficial effect after a time? Should it be applied to a compost heap? How can this waste be avoided? How would you test for the escaping NH_3 ?

117. Action of lime on copperas? How does the copperas get in the soil? Symbol and equivalent of carbonate of lime (CaCO_3)? Source? How are stalactites and stalagmites formed?

118-19. What is petrified moss? Whiting? Marble? Chalk? Marl? Symbol and equivalent of sulphate of lime (calcium sulphate, CaSO_4)? Common names? What is plaster of Paris? Why does plaster of Paris harden, if moistened? *Ans.*—Because it absorbs water again. Uses? Tell the story of Franklin. What is the difference between sulphate and sulphite of lime? Symbol and equivalent of phosphate of lime (p. 245)? What is the super-phosphate? Use?

MAGNESIUM.—Symbol and equivalent? Source? How can you tell if a stone contains Mg ? Properties? For what is it noted? Name the two classes of rays contained especially in its light (Phil., p. 206). For what purposes do the colorific rays adapt it? Does it contain heat-rays also? *Ans.*—Very few.

121. Product of its combustion? What prevents its extensive use? Symbol and equivalent of carbonate of magnesia (magnesium carbonate, MgCO_3)? What is calcined magnesia? Epsom salt (magnesium sulphate, $\text{MgSO}_4 + 7\text{H}_2\text{O}$)?

ALUMINUM.—Symbol and equivalent? Common name? Source? Properties? Solvent? What can you say of its abundance and probable usefulness? What is alumina? What crystals and gems does it form? What is emery? Symbol and equivalent of silicate of alumina? Common name? Source? Use in the soil? In the arts? What is ochre? Fuller's earth? Explain the process of glazing pottery ware. The salt glaze? The litharge glaze? What objection to the latter? What gives color to brick? What is the peculiarity of white brick? Symbol and equivalent of alum? Preparation? Uses? What is an iron or a chrome alum? Burnt alum? How are alum crystals made? Describe spectrum analysis. (Astronomy, page 284.) What is the spectroscope?

IRON.—Symbol and equivalent? Tell what you can of its value to the world. How is its use a symbol of a nation's progress? State how its value is enhanced by labor. Name the three oxyds of iron. State where each is found. Cause of the changing colors seen in the scum over standing water (Phil. p. 209)? Why do brick turn red in burning? Origin of yellow sand? Describe the process of smelting iron ore. Why is hot air used for the draft? Reaction of the lime? What becomes of the O in the ore? Origin of the term "pig-iron?" Properties? Illustrate its malleability. Why do cannon, axles of cars, etc., become brittle by use (Phil. p. 39)? What difficulty arises in casting large cannon (p. 245)? What exception adapts iron for use in castings? What does this teach us? Name the three forms of iron. The difference? How is cast-iron made? Properties? What is "chilled" iron? Why is it tougher than cast-iron? How is wrought or malleable iron made? Properties? How does a blacksmith temper his work? What is steel? How made? Describe Bessemer's process. In making steel tools, how does the workman judge of the temper? How are cheap knives made? What is galvanized iron? Symbol and equivalent of bisulphide of iron (ferrous bisulphide)? Common names? Test? Symbol and equivalent of the sulphate of iron (ferrous sulphate, $\text{FeSO}_4 + 7\text{H}_2\text{O}$)? Common names? Preparation? Uses?

ZINC.—Symbol and equivalent? Source? Preparation? Reaction? Is it malleable? Will it oxydize in the air? What causes the white coating when we spill water on the zinc under

our stove? What is "philosophers' wool?" Uses of Zn? What is zinc-white?

TIN.—Symbol and equivalent? Where found? What is common tin-ware? Action of NO_2 on Sn? What is mosaic gold? What can you say of the manufacture of pins?

COPPER.—Symbol and equivalent? Where found? Preparation (p. 246)? Antiquity of the mines? What is malachite? Properties of Cu? Color of its vapor? How tempered? What is verdigris? Carbonate of copper? Black oxyd of copper? What is the danger of using a copper kettle? Is it well to "scald" pickles in one? Solvent of Cu? Test? Symbol and equivalent of sulphate of copper (copper sulphate, CuSO_4)? Common name? Uses? What are the names and symbols of all the "vitriols?"

LEAD.—Symbol and equivalent? Source? Preparation? Properties? Its effect on the human system? On water? Is there more danger with hard, or with soft water? What precaution should always be used with lead pipes? What is "litharge?" Its uses? "Red-lead?" Its uses? What is "white-lead?" Describe its manufacture. With what is it adulterated? Test? What is "sugar of lead?" (The dash over the A signifies an organic acid. Example: Oxalic acid $\equiv \bar{\text{O}}$; tartaric acid, $\bar{\text{T}}$.) Properties? Antidote? Explain the formation of the lead-tree. Test of Pb? Name? Other tests?

ARSENIC.—Symbol and equivalent? Common name? Test? What is commonly sold as arsenic or ratsbane? Preparation of arsenious acid? Properties? What can you tell of its antiseptic property? Antidotes? Describe Marsh's test. Arsenic eating? In what form is chromium usually seen? What is its common salt? Its use? Describe cobalt (p. 246). If we ask for cobalt at the drug-store, what will we get? If we ask for arsenic? For what is chloride of cobalt used? Describe manganese. Chameleon mineral (permanganate of potash)? Nickel? Bismuth? Antimony?

MERCURY.—Symbol and equivalent? Why so called? Source? Tell the story of its discovery in Mexico. Properties? Solvent? What two elements are fluid at ordinary temperatures? What is an amalgam? Should we touch any gold ornament to Hg? Uses? What is blue-pill? Mercurial ointment? Calomel? How distinguished from corrosive sublimate? Action of Hg on the system? For what is "red precipitate" noted? What is the chloride of mercury commonly called? Properties? Uses? Antidote? Of what were mirrors anciently made? Process of silvering mirrors? Effect on the workmen?

IRIDIUM.—Why so called? For what is it noted? Use?

PLATINUM.—Symbol and equivalent? Where found? Properties? Use? Describe Wollaston's method of drawing platinum wire.

GOLD.—Symbol and equivalent? Source? Origin of the gold washings of California? Preparation? Properties? Solvent? Process of making gold-leaf?

SILVER.—Symbol and equivalent? Sources? Preparation (1) from the sulphuret, (2) horn silver, (3) lead? Describe the process of reduction at the West (p. 252). What is cupellation? Properties? Why does silver blacken, if handled? Why do door-knobs, silver spoons, etc., tarnish? What effect has coal-gas? Solvent? Test? Why is a solution of a coin blue? What is the common name of nitrate of silver? What is its action on the flesh? How may its stain be removed? Uses? Of what are hair-dyes and indelible inks made? Why will a solution of nitrate of silver curdle brine? Describe the process of daguerreotyping (p. 248). Photography. Why will writing with indelible ink turn black by ironing or exposing it to the sun?

THE ALLOYS.—What is type-metal? Britannia ware? Brass? German silver? Nickel silver? (Phil., p. 300.) Soft solder? Hard solder? Fusible metal? Bronze? Describe the composition of coin? Meaning of the term carat? Describe the manufacture of shot. What is oreide? Aluminum alloy?

ORGANIC CHEMISTRY.

INTRODUCTION.—Is matter dead? What can you say of the proofs of Infinite design and wisdom found in nature? Can we use the elements of matter directly? What is the office of the plant? Name some of the products of this vegetable loom. Define organic chemistry. State the differences between organic and inorganic chemistry.

156-7. What do you say of the number of organic compounds? Can they be made artificially, or must we depend on plants? What is Isomerism? Allotropism? What is a radical (p. 252)? Symbol and equivalent of starch? Name the various sources. How can you prove that starch exists in potatoes, apples, etc.? Why is it stored in the seed? Why in the starch form? How can the different kinds of starch be distinguished? Preparation? Properties? Cause of the swelling of rice, beans, etc., when soaked? What proof can you give that starch is insoluble in cold water? What is dextrine? Test? Sago? Tapioca? What is the second allotropic form

of starch? Source? The third allotropic form? Source? Why can jelly be made from fruit only at a certain stage of ripening? Fourth form? Sources? Use in the plant? What can you say of the power of secretion possessed by the plant-cell? Uses of woody fibre? Describe the process of paper-making. How is paper parchment made? Tell how linen is prepared. What is cotton? What makes unbleached goods so yellow? How is gun-cotton made? What do you say of its explosive force? What is collodion? Uses (p. 251)? What is eremacausis? Why does decaying wood turn black? Describe the destructive distillation of wood. What are the products? Use of wood-tar? What are the products of its distillation? How is pyroligneous acid made? Uses? What is creosote? How can hams be cured instantly? Why will smoke cure hams and make us cry? How is tar made? Turpentine? Rosin? Coal-tar? Uses of coal-tar? Products of its distillation? Probable origin of petroleum? How is it rectified? What is the lightest oil called? The heaviest? How is bitumen formed? Name places where it is found. What was Greek fire? Symbol and equivalent of cane-sugar? Describe its manufacture. The refining of sugar. Give experiment showing the presence of C in sugar. What is rock-candy? Tell what you can about confectionery. How is candy adulterated? Test of pure candy? How are licorice-drops made? Gum-drops? Is colored candy safe? What is caromel? Use? Why does sugar turn black when it boils over on our stoves? Symbol and equivalent of grape-sugar? Where found? Tell how sugar may be made from starch or wood. Why do fruits lose their sweetness if over-ripe? When should grass be cut? Why does maple-sap lose its sweetness when the leaf starts? Why is it sweet again in the autumn? Why are frozen potatoes sweet?

FERMENTATION.—Name the two stages in ordinary fermentation. Describe the change in each. Give the reaction. Are there not other kinds of fermentation than those named in the text? What is yeast? What are yeast-cakes? Ought yeast-cakes or "sponge" to freeze? What is malt? Describe the process of making it. What is gluten? Its use? Diastase? Its use? Why is malt sweet? Describe the process of brewing beer. What causes its foaming? What is lager-bier? Describe the process of making wine. What causes the effervescence? The acidity? What is the amount of alcohol in various liquors? Why will wine sour if the bottle is not well corked? Tell from what each kind of liquor is distilled. How is alcohol manufactured? Properties? What is anhydrous

or absolute alcohol? Uses of alcohol? Effect on the system or brain? How is sulphuric ether made? Explain the chemical change. How are other ethers made? Why are they thus named? What is fusel oil? Is it poisonous? Should it be contained in liquor? Use in making flavoring extracts? How is chloroform made? Properties? How is acetic acid made in ordinary fermentation? What acid in vinegar? How is acetic acid made for commerce? State how cider-vinegar is made. What is "mother?" Effect of vinegar on food? On digestion? On young ladies? Why can vinegar be made from tea-leaves and sweetened water? Why will molasses strengthen vinegar? Why should the vinegar barrel be kept in a warm place? How is the vinegar of the shops sharpened? How may this be detected? The English method of making vinegar? Describe the quick-vinegar process. What is the use of the shavings? Cause of the working of preserves? Why does scalding check the process?

VEGETABLE ACIDS.—What are vegetable acids? Symbol and equivalent of oxalic acid? Sources? Preparations? Is it poisonous? Antidote? If $\bar{O}$ is poisonous, why is not rhu-barb also? What are "salts of lemon?" How may ink-stains be removed? Where is tartaric acid found? What is cream of tartar? Preparation of $\bar{T}$? Properties? Why does its solution turn mouldy? What is Rochelle salts? Seidlitz powders? Tartar emetic? Citric acid? Malic acid? Tannic acid? Nut-galls? Properties of tannic acid? Describe the process of tanning. Why is leather black on one side? Why do drops of tea stain a knife-blade? How is ink made? Why does it darken by exposure to the air? Object of gum, cloves, &c., in the ink? Why are steel-pens corroded by ink? What compound is formed? What is gallic acid?

OILS AND FATS.—Difference? What two divisions? What is the constitution of the fixed oils? Which of these form fats? Oils? What determines the fluidity of a fatty substance? What is lard-oil? Why is olive-oil fluid in summer and solid in winter? Describe glycerin. Uses? What causes the bad smell of a smouldering wick? What is nitro-glycerin? Lye? How is lye made? In what form is the alkali in the ashes? In the plant? Where does the CO_2 come from? Why is lime put in the bottom of the leach-tub?

185. How are home-made soaps made? Reaction? What becomes of the glycerin? Why is the soap soft? What is hard soap? Why hard? How may hard soap be made from soft soap? Reaction? Which will make harder soap, tallow or lard? How is Castile soap made? Yellow soap? Shaving-

soap? Soap-balls? Toilet-soap? Why are washing-fluids injurious? Explain the action of soap in hard water. Reaction? Explain the cleansing qualities of soap. Cause of the soapy feeling? Why does new soap act on the hands so much more than old soap? What are soapsuds? How is soap adulterated? How can this be detected? Describe the process of making stearin. (It is also prepared by the action of superheated steam, which breaks up the lard into its constituents.) From what are paraffine candles made? Describe the process of making wax-candles. Wax-tapers. What is spermaceti? What is the shiny coating on leaves and fruit? How do the Japanese make candles? Where do the bees obtain their wax? How is wax bleached? What is a drying-oil? How is linseed-oil made? What is "boiled" oil? Putty? Printers' ink? Cod-liver oil? Croton-oil? Castor-oil? What is an unctuous oil? What is sweet-oil?

VOLATILE OILS.—Difference between these and the fixed? Source? What causes the perfume of flowers? What is attar-of-roses? Describe the process of making peppermint and other essences. What is rose-water? How are the delicate perfumes extracted? How is oil-of-lemon obtained? Name the oils which are isomeric. What is their composition? How do you account for the variety of their flavor and odor? What is spirits of turpentine? Why does it burn with so much smoke? How is it changed to rosin? Why is the nozzle of the turpentine-bottle always sticky? What is camphene? Burning-fluid? Why does burning-fluid give more light than alcohol and less smoke than camphene? How is artificial camphor made? What are "the camphors?" How is camphor obtained? Why are the vapors condensed on rice-straw? Is camphor poisonous? Its solvent? Would you weaken spirits of camphor with water? What oils comprise the third class? Why should not mustard be used when first prepared for the table?

RESINS AND BALSAMS.—How are resins formed? What is a balsam? Why does cherry-juice harden into gum? Properties of the resins? What is the difference between rosin and resin? How is rosin made? Uses? How is shoemakers' wax made? What is lac? Name the different kinds. What is varnish? How is gum benzoin obtained? Uses? What is amber? Origin? How do you know that it is so ancient? Uses? What is caoutchouc? Describe the process of obtaining it. Its solvents? How are suspenders, rubber cord, &c., made elastic? What is vulcanized rubber? Tell the story of its discovery. How can rubber be made hard and black? Uses? What can you say about gutta-percha?

ORGANIC BASES.—Why so named? Solvent? Poisonous properties? Antidote? What is opium? Describe the process of gathering it. Properties (p. 257)? Describe the process of opium-smoking. What is morphine? Why is it called morphine and also morphia? Uses? Laudanum? Paregoric? Quinine? Uses? Nicotine? Why does tobacco vary in its stupefying properties? What is strychnine? Solvents? Taste? Poisonous property? Antidote? What is the chromatic test? Can death by arsenic be readily detected? By organic poisons? Describe the method. What are caffeine and theine? What do you say of the gluten in tea? Why should browned coffee be kept tightly corked? Describe the process of raising tea. Of curing black-tea. How do the Chinese prepare tea? Process of curing green-tea? What can you say of the adulteration of teas? Why does one feel sleepy after eating lettuce?

ORGANIC COLORING PRINCIPLES.—What is their origin? Can we dye cloth directly? What are substantive colors? Mordants? Name the most common mordants. Show how one dye may be made to produce several colors. Describe the process of printing calico. What is madder? Cochineal? What can you say about the ancient purple? How can red ink be made? Describe the process of obtaining indigo. How does indigo change from yellow to blue? How can the color be removed? What is litmus? How is its color obtained? What is leaf-green (chlorophyll)?

ALBUMINOUS BODIES.—Name and describe. Why called protein? Where is albumen found? What is said of the venom of the rattlesnake? Properties of albumen? Why do eggs harden when cooked? Why is the white of an egg an antidote for corrosive sublimate and other poisons? Why can we settle coffee with an egg? What peculiar property has albumen? How is vegetable albumen formed? What is fibrin? How may it be obtained? What causes the clotting of blood? What is gluten? When we chew wheat, what dissolves out and what is left in the gum? Where is casein found? Cause of the souring of milk? Curdling? How can vegetable casein be obtained? For what do the Chinese use it? What is gelatin? What is said of it as an article of food? What is glue? Isinglass? Size? What other name for vegetable gelatin? Where found? What is milk? Why does cream rise on milk? Explain the theory of churning. Why does the addition of warm water "make the butter come?" Describe the souring of milk. What acts as the ferment? Why does boiling milk prevent its souring? Is there any truth in the common idea that thunder sours milk? Why will soda

sweeten milk, if only slightly "turned?" Why does milk sour in churning? Why does milk sour on the stomach? What is the composition of bones? How can the mineral matter be removed? The organic matter? Does the blood circulate through the bones? How is this shown? What can you say of putrefaction? Why is there need of caution in dissection? Why is the heart of a tree more durable than the sap-wood? What is kyanizing? Why do dried fruits, meats, &c., keep? How does salt act? Why does salting harden and toughen meat? Is salted meat good for a student? Why does not frozen meat spoil?

DOMESTIC CHEMISTRY.—Describe the process of bread-making. What causes the bread to rise? What is the need of kneading? Why does the loaf swell up when put in the oven? Cause of slack-baked bread? Of a hollow loaf? Why is a burnt crust black? How is rusk made? Is there a loss in this process of fermentation? Describe the process of making "milk-emptyings" bread. Why is a uniform temperature necessary? What is "salt-rising" bread? What can you say of the water in bread? How is "aerated bread" made? Cause of sour bread? How remedied? How are pancakes raised? Describe biscuit-raising. Reaction? How can the adulteration in cream of tartar be detected? What are Prof. Hosford's baking-powders? What is the reaction of soda and HCl when used in baking? What is probably the most healthy kind of bread? Ought food with yellow streaks of saleratus in it to be used at all? Explain the process of raising with sal-volatile. Why is toasted bread healthy? Crust coffee? What can you say of cooking potatoes? Why is fried food unhealthy? What methods of cooking are best? How should broiling be conducted? Should meat be boiled in hot or in cold water? In making soup, should we use hot or cold water? How will over-boiling injure soup? What caution should be observed in baking meat? What is the reaction when meat burns? Describe the effect of water in cooking. Will peas and beans cook soft in hard water? When should salt be added to the water in which vegetables are cooking? What can you say of the quantity of food we require annually? What becomes of this large amount? What does this prove? What effect does food have on the temperament? What is the effect of alcohol, sugar, &c.? Why is unbolted flour best? Is pork as nourishing as beef? Show how climate prescribes the kind of food. Why do we wish butter on fish, eggs with tapioca, oil on salad, and boil rice with milk?

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1 lb.	Black Oxyd of Manganese.	¼ oz.	Chloride of Barium.
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¼ "	Chlorate of Potash.	12 "	Tartaric Acid.
1 "	Alum.	12 "	Chloride of Mercury.
12 "	Sulphur.	12 "	Metallic Antimony.
12 "	Caustic Potash (Sticks).	12 "	Arsenious Acid.
12 "	Sugar of Lead.	12 "	Iodide of Potassium.
12 "	Bichromate of Potash.	12 "	Iodine.
2 "	Bone-Black.	12 "	Potassium.
2 "	Sulphuret of Iron.	12 "	Sodium.
1 "	Nitrate of Potash.	12 "	Solution Chloride of Platinum.
1 "	Chloride of Ammonium.	4 "	Sulphuric Ether.
12 "	Yellow Prussiate of Potash.	12 "	Chloride of Cobalt Solution.
12 "	Red " " "	12 "	Bisulphide of Carbon.
12 "	Oxalic Acid.	12 "	Phosphuret of Calcium (Pieces).
12 "	Ground Nut-Gall.	1 "	Litharge.
12 "	Phosphorus.	12 "	Nitrate of Silver Solution.
2 "	Fluor Spar.	2 "	Sulphate of Iron.
12 "	Litmus.	2 "	Sulphate of Copper.
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1	Specimen Metal, Aluminum.	6 sheets	Filtering Paper.

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1	Alcohol Lamp—4 oz.	2	Tubes for Hydrogen Tubes.
2	Evaporating Dishes.	¼ lb.	French Glass Tubing.
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6	Assorted Test Tubes.	1	Small Lead Tray.
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